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DESIGNER'S HANDBOOK - INSTALLING THERMAL PIPELINE SYSTEMS. PART--ETC(U)
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FOREIGN TECHNOLOGY DIVISION

DESIGNER'S HANDBOOK
INSTALLING THERMAL PIPELINE SYSTEMS

by

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Table of Contents

U.S. Board on Geographic Names Transliteration System..... iii

Preface..... 2

Section I..... 5

Chapter 1. General Reference Materials..... 5

Chapter 2. Tubes and Parts of Conduit..... 25

Chapter 3. Supports of Turboconductors..... 65

Chapter 4. Fittings, Flange Joints, Gasket and Corrugated Compensators..... 117

Chapter 5. Drainage Devices of Conduit..... 168

Section II. Diagrams and Calculations of Thermal Networks... 228

Chapter 6. Diagrams of Thermal Networks..... 228

Chapter 7. Determination of Heat Consumption..... 247

Chapter 8. Regulation of Heat Distribution..... 275

Chapter 9. Hydraulic Designs of Pipelines..... 338

Chapter 10. Stress Analysis of Pipeline and for the Compensation for Thermal Elongations..... 490

Chapter 11. Loads on Supports of Pipelines..... 694

Section III. Laying of Thermal Networks..... 731

Chapter 12. Overall Questions of Packing..... 731

Chapter 13. Heat Insulation..... 794

Chapter 14. Protection of Conduit from Electrical Corrosion..... 825

Section IV. Pumping and Preheating Installations, Thermal Point..... 974

Chapter 16. Quality and Quantity of Makeup Water of Water Thermal Networks..... 974

23 09 08 051

Chapter 17. Pumping Stations..... 995
Chapter 18. Preheating Insta lations..... 1031
Chapter 19. Thermal Point..... 1082
Section V. Heat Control and Automation of Thermal Networks 1107
Chapter 20. Heat Control and Automation..... 1107
Section VI. Technical and Economical Indices..... 1179
Chapter 21. Combined Technical and Economic Indices..... 1179
References..... 1199

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Page 105.

Chapter 9.

HYDRAULIC DESIGNS OF PIPELINES.

9.1. Basic condition/positions.

The basic task of hydraulic design of the pipelines of thermal grid/networks is the determination of the diameters of pipelines and losses of pressure with the assigned/prescribed coolant flow rates or the determination of pipeline flow efficiency with the assigned/prescribed available pressure differential.

The determination of the diameters of pipelines is produced by the total winter calculated hourly consumptions of heat carrier. Independent of the results of calculation the throat diameters of tubes are accepted: for distribution networks 40 mm and for branches to separate buildings 25 mm.

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For the selected diameters of the pipelines of water thermal grid/networks if necessary, are determined the losses of pressure with the consumption of water, which differ from the calculated: summer, during maximum selection to hot water supply in two-funnelled grid/networks in the open system, etc. The results of calculations are considered when selecting of the characteristics of the network and booster pumps and during the development of hydraulic (hydrodynamic) conditions/modes.

During the determination of the diameters of steam lines, specific losses of pressure on friction calculate on the basis of the taken jump/drop in the pressures pair, considering its initial parameters of heat source and assigned/prescribed - in user. In steam lines is determined also a temperature drop pair that has important value at the assigned/prescribed final temperature the pair in user.

When selecting of the diameters of composite condensate pipings, specific losses of pressure determine on the basis of pressure differentials among condensate removal device and by receiver tank of condensate taking into account the

possibility of the formation of steam-water mixture because of the partial effervescence of condensate at a pressure drop than lower corresponding to saturation temperature.

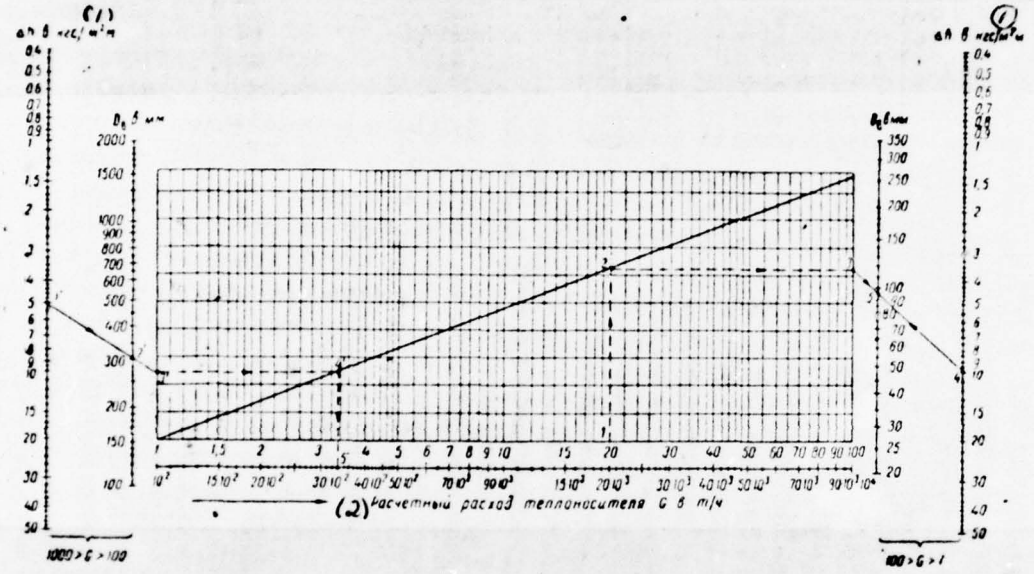


Fig. 9.1. Nomogram for hydraulic design of pipelines of water thermal grid/networks with $k_э$=0,5 mm and γ = 958 kG/m³.

Example 1. It is given to G = 20 m/h; Δh = 10 kgf/m² m. Connecting in series points 1, 2, 3 and 4, we find in point 5 $D_в$=95,5 mm.

Example 2. Is given $D_в$=310 to mm; Δh = 5 kgf/m² m. Connecting consecutively of point 1', 2', 3', 4', we find in point 5'G = 330 t/hs.

Key: (1). kgf/m² m. (2). Calculated coolant flow rate G in t/h.

Page 106.

For approximate hydraulic designs of water thermal grid/networks, is given the nomogram of Fig. 9.1.

The throughput capacity of thermal grid/networks for the average conditions of the transport of heat carrier can be approximately determined by Table 9.1-9.4.

Table 9.1. The pipeline flow efficiency of water thermal grid/networks ($k_э = 0,5$ mm; γ = 958.4 kg/m³).

(4) Условный проход труб $D_у$ в мм	(2) Пропускная способность в т/ч при удельной потере давления на трение Δh в кгс/м² м				(3) Пропускная способность в Гкал/ч при температурных графиках в °С											
					150—70				130—70				95—70			
	(4) Удельная потеря давления на трение Δh в кгс/м² м															
	5	10	15	20	5	10	15	20	5	10	15	20	5	10	15	20
25	0,45	0,68	0,82	0,95	0,04	0,05	0,07	0,08	0,03	0,04	0,05	0,06	0,011	0,017	0,02	0,024
32	0,82	1,16	1,42	1,54	0,07	0,09	0,11	0,12	0,05	0,07	0,08	0,09	0,02	0,029	0,025	0,028
40	1,38	1,94	2,4	2,75	0,11	0,15	0,19	0,22	0,08	0,12	0,14	0,16	0,035	0,05	0,06	0,07
50	2,45	3,5	4,3	4,95	0,2	0,28	0,34	0,4	0,15	0,21	0,26	0,3	0,06	0,09	0,11	0,12
70	5,8	8,4	10,2	11,7	0,47	0,67	0,82	0,94	0,35	0,51	0,61	0,7	0,15	0,21	0,25	0,29
80	9,4	13,2	16,2	18,6	0,75	1,05	1,3	1,5	0,56	0,79	0,97	1,1	0,23	0,33	0,4	0,47
100	15,6	22	27,5	31,5	1,25	1,75	2,2	2,5	0,93	1,32	1,65	1,9	0,39	0,55	0,68	0,79
125	28	40	49	56	2,2	3,2	3,9	4,5	1,7	2,4	2,9	3,4	0,7	1	1,23	1,4
150	46	64	79	93	3,7	5,1	6,3	7,5	2,8	3,8	4,7	5,6	1,15	1,6	1,9	2,3
175	79	112	138	157	6,3	9	11	12,5	4,7	6,7	8,3	9,4	1,9	2,8	3,4	3,9
200	107	152	186	215	8,6	12	15	17	6,4	9,1	11	13	2,7	3,8	4,7	5,4
250	180	275	330	380	14	22	26	30	11	16	20	23				
300	310	430	530	600	25	34	42	48	19	26	32	36				
350	455	640	790	910	36	51	63	73	27	68	47	55				
400	660	930	1 150	1 320	53	75	92	106	40	56	69	79				
450	900	1 280	1 560	1 830	72	103	125	147	54	77	93	110				
500	1 200	1 690	2 050	2 400	96	135	164	192	72	102	123	144				
600	1 880	2 650	3 250	3 800	150	212	260	304	113	159	195	228				
700	2 700	3 800	4 600	5 400	216	304	368	432	162	228	276	324				
800	3 800	5 400	6 500	7 700	304	443	520	615	228	324	390	460				
900	5 150	7 300	8 800	10 300	415	585	705	825	310	437	527	617				
1000	6 750	9 500	11 600	13 500	540	760	930	1080	405	570	558	810				
1200	10 700	15 000	18 600	21 500	855	1200	1490	1750	640	900	1100	1290				
1400	16 000	23 000	28 000	32 000	1280	1840	2240	2560	960	1380	1680	1920				

Note. Throughput capacity in gcal/h is given for purely heating load.

Key: (1). The internal diameter of tubes D_y in mm. (2). Throughput capacity in t/h with specific loss of pressure on friction Δh in kgf/m² m. (3). Throughput capacity in gcal/h with temperature curve/graphs in °C. (4). Specific loss of pressure on friction Δh in kgf/m² m.

Table 9.2. Throughput capacity in t/h of steam lines with U-shaped compensators with the loss of pressure on the order of 1 atm(tech)/km taking into account local resistance ($k_э$=0,2 mm).

(1) Условный проход труб D_y в мм	(2) Параметры пара $P_{раб}$ в кгс/см², t в °С, γ в кгс/м³				
	$P_{раб}$=8, t=250, γ=3,35	$P_{раб}$=13, t=300, γ=4,98	$P_{раб}$=16, t=325, γ=5,85	$P_{раб}$=21, t=350, γ=7,18	$P_{раб}$=36, t=425, γ=11,79
25	0,035	0,045	0,05	0,055	0,07
32	0,06	0,08	0,085	0,095	0,12
40	0,1	0,13	0,14	0,16	0,2
50	0,2	0,24	0,26	0,29	0,37
70	0,45	0,55	0,6	0,67	0,85
80	0,73	0,9	0,95	1,1	1,3
100	1,2	1,5	1,6	1,7	2,3
125	2,2	2,7	2,9	3,2	4,1
150	3,5	4	4,5	5	6,5
175	5,5	7	7,5	8	11
200	7,5	9,5	10	11	15
250	13	17	18	20	25
300	21	26	28	31	39
350	31	39	42	47	58
400	45	56	58	65	81
450	59	72			
500	77	95			
600	118	140			
700	165	200			
800	235	285			
900	315	385			
1000	415	500			

Key: (1). Conditional passage of tubes D_y in mm. (2). Parameters pair P_{pa6} in kg/cm², t in °C, γ in kg/m³.

Page 107.

9.2. Basic calculation formulas.

Loss of pressure on the section of pipeline is determined from the formula

$$\Delta H = \Delta H_{тр} + \Delta H_{м} = \Delta h l_{пр} \text{ kgf/m}^2 \quad (9.1)$$

where $\Delta H_{тр}$ - loss of pressure on friction in kgf/m²;

$\Delta H_{м}$ - loss of pressure in local resistance in kgf/m²;

Δh - specific loss of pressure to friction in kgf/m² m;

$l_{пр}$ - the reduced length of pipeline in m.

Loss of pressure on friction is determined from the formula

$$\Delta H_{тр} = \Delta h l \text{ kgf/m}^2 \qquad (9.2)$$

where l is length of the section of pipeline according to the plan in m.

Loss of pressure in local resistance is determined from the formula

$$\Delta H_{м} = \frac{v^2}{2g} \gamma \Sigma \xi = \Delta h l_э \text{ kgf/m}^2 \qquad (9.3)$$

where $l_э$ is equivalent length of local resistance in m;

v - the rate of heat carrier in m/s;

g = 9.8 m/s^2 - the acceleration of the freely falling/incident body;

γ - the average specific gravity/weight of heat carrier on the designed section of pipeline in kG/m^3;

$\Sigma\xi$ is a sum of the coefficients of local resistance on section;

ξ - the value of coefficients for each form of local resistance (catch, valve/gate, branch/removal and so forth).

Specific loss of pressure on friction is determined from the formula

$$\Delta h = \lambda \frac{v^2 \gamma}{2gD_в} = 0{,}00638\,\lambda \frac{G^2}{D_в^5 \gamma} \text{ kgf/m}^2 \quad (9.4)$$

where λ is a coefficient of hydraulic frictional resistance (value dimensionless);

G - calculated coolant flow rate on the designed section in t/h;

$D_в$ - tube bore in m.

The reduced length of pipeline is determined from the formula

$$l_{пр} = l + l_э \text{ м}. \quad (9.5)$$

The equivalent length of local resistance is determined from the formula

$$l_э = \sum \xi \frac{D_в}{\lambda} \text{ м}. \quad (9.6)$$

The welded butt welds of tubes during the calculation of the equivalent length of local resistance are not considered.

In the absence of the data on character and number of local resistance on pipeline the equivalent length of local resistance can be determined approximately according to the formula

$$l_э = \alpha l \text{ м}, \qquad (9.7)$$

where α - the coefficient, which considers the portion of a pressure drop in local resistance with respect to drop in pressure to friction, it is possible to accept according to Table 9.5.

Bore and pipeline flow efficiency, but also the rate of heat carrier are determined from the formulas:

$$D_э = \sqrt[5]{\frac{0{,}00638\,\lambda G^2}{\Delta h \gamma}} \text{ м}; \qquad (9.8)$$

$$G = 12{,}5\sqrt{\frac{D_э^5\,\gamma\Delta h}{\lambda}} \text{ т/ч} \qquad (9.9)$$

$$v = 0{,}354\,\frac{G}{\gamma D_э^2} \text{ м/с}. \qquad (9.10)$$

Table 9.3. Throughput capacity in t/h of steam lines with gasket compensators with the loss of pressure on the order of 1 at on 1 km taking into account local resistance ($\lambda_э$=0,2 ■■).

(1) Условный проход труб D_y в мм	(2) Параметры пара $P_{раб}$ в кгс/см², t в °С, γ в кгс/м³			
	$P_{раб}$=8, t=250, γ=3,35		$P_{раб}$=12,5, t=300, γ=4,78	
	(3) транзитные сети	(4) разветвленные сети	(3) транзитные сети	(4) разветвленные сети
100	1.3	1,3	1.6	1,5
125	2,4	2.3	2.9	2,7
150	3.9	3.7	4.7	4.3
175	6.9	6.4	8.2	7 5
200	9.4	8.5	11	10.3
250	16.8	15.6	20	18.5
300	26	24	31	29
350	39	36	47	43
400	56	53	67	62
450	78	68	93	83
500	102	90	120	108
600	160	140	190	170
700	225	200	270	240
800	320	285	380	340
900	430	385	515	460
1000	570	500	670	600

Key: (1). The internal diameter of tubes D_y in mm. (2). Parameters pair $P_{раб}$ in kg/cm^2, t in °C, γ in kg/m^3. (3). transit grid/networks. (4). branched grid/networks.

Table 9.4. The throughput capacity of condensate pipings in t/h ($k_э$=1 мм; γ = 958.4 kg/m³).

(1) Условный проход труб D_y в мм	(2) Удельная потеря давления на трение Δh в кгс/м²м			
	5	10	15	20
25	0,41	0,58	0,72	0,83
32	0,71	1,02	1,24	1,42
40	1,2	1,7	2,07	2,4
50	2,2	3,1	3,8	4,4
70	5,2	7,4	9,1	10,5
80	8,2	11,5	14	16,5
100	14	20	24	28
125	25	36	44	51
150	41	58	72	82
175	72	100	125	140
200	98	135	165	195
250	180	250	310	350
300	280	400	500	560
350	420	590	720	840
400	610	860	1050	1220
450	820	1180	1450	1650
500	1100	1550	1900	2200

Key: (1). The internal diameter of tubes D_y in mm. (2). Specific loss of pressure on friction Δh in kgf/m² m.

During the turbulent state of motion of heat carrier the coefficient of hydraulic frictional resistance λ for steel tubes is determined from the formulas: for turbulent motion in the region of quadratic law when $Re \geqslant Re_{пр}$ by the Prandtl-Nikuradze formula

$$\lambda = \frac{1}{\left(1{,}14 + 2\lg\frac{D_в}{k_э}\right)^2}, \qquad (9.11)$$

where $k_э$ is equivalent roughness of tube in m;

Re - Reynolds number;

$Re_{пр}$ - the limiting value of Reynolds number;

for turbulent motion in transition region when $Re < Re_{пр}$ along the formula of Colbrook-White

$$\lambda = \frac{1}{\left[-2\lg\left(\frac{2{,}51}{Re\sqrt{\lambda}} + \frac{k_э}{3{,}7D_в}\right)\right]^2}. \qquad (9.12)$$

For the facilitation of the calculations of formula (9.11) and (9.12) are represented in graphic form (Fig. 9.2 and 9.3).

Reynolds number is determined from the formula

$$Re = \frac{vD_в}{\nu}, \qquad (9.13)$$

where ν - the kinematic viscosity of heat carrier in m^2/s.

The value of Reynolds number can be determined by the nomograms of Fig. 9.4 and Fig. 9.5.

The kinematic viscosity of heat carrier are determined from the formula

$$\nu = \frac{\mu g}{\gamma} \ m^2/s \qquad (9.14)$$

where μ - the dynamic viscosity of heat carrier in kgf s/m^2;

g = 9.8 m/s^2 is acceleration of the freely falling/incident body.

The limiting value of Reynolds number, which characterizes the boundary/interface of transition region and region of quadratic law, is determined from the formula

$$Re_{np} = 560 \frac{D_э}{k_э}. \qquad (9.15)$$

Table 9.5. Coefficient α for determining the total equivalent lengths of local resistance.

(1) Типы компенсаторов	(2) Условный проход труб D_y в мм	(3) Значения коэффициента α	
		(4) для паропроводов	(5) для водяных тепловых сетей и конденсатопроводов
	(6) Транзитные магистрали		
(7) Сальниковые	(8) До 1000	0,2	0,2
(9) П-образные с гнутыми отводами	300	0,5	0,3
	200—350	0,7	0,5
(10) П-образные со сварными отводами	400—500	0,9	0,7
	600—1000	1,2	1
	(11) Разветвленные тепловые сети		
(7) Сальниковые	(8) До 400	0,4	0,3
	450—1000	0,5	0,4
(9) П-образные с гнутыми отводами	До 150	0,5	0,3
	175—200	0,6	0,4
	250—300	0,8	0,6
(10) П-образные со сварными отводами	175—250	0,8	0,6
	300—350	1	0,8
	400—500	1	0,9
	600—1000	1,2	1

Key: (1). Types of compensators. (2). The internal diameter of tubes D_y in mm. (3). Values of coefficient α. (4). for steam lines. (5). for water thermal grid/networks and condensate pipings. (6). Transit main lines. (7). Gasket.

(8). To. (9). U-shaped with the bent branch/removals. (10). U-shaped with welded branch/removals. (11). Branched thermal grid/networks.

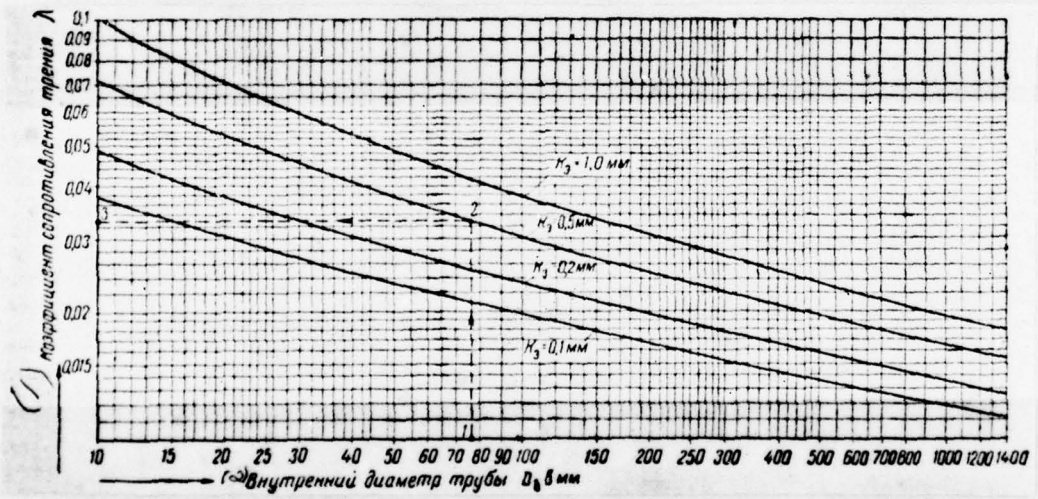


Fig. 9.2. Graph for determining coefficient of friction drag in region of quadratic law when $Re \geqslant Re_{пр}$

Key: (1). Coefficient of friction drag λ. (2). Tube bore $D_в$ in mm.

Page 109.

To the limiting values of Reynolds number Re_{np} correspond the limiting values of the velocities of heat carriers v_{np} and of maximum discharges G_{np}, which they are determined from the formulas:

$$v_{np} = 560 \frac{\nu}{k_э} = 5480 \frac{\mu}{\gamma k_э} \text{ m/s} \qquad (9.16)$$

$$G_{np} = 560 \frac{\gamma\nu}{0,354} \cdot \frac{D_в^2}{k_э} = 15\,500\,\mu \frac{D_в^2}{k_э} \text{ t/h.} \qquad (9.17)$$

The ratio of equivalent roughness to tube bore $\frac{k_э}{D_в}$ is called relative equivalent roughness.

During hydraulic designs of the pipelines of thermal grid/networks the value of equivalent roughness is taken:

for water thermal grid/networks. ... $k_э = 0.5$ mm

For steam lines. ..... $k_э$=0.2 mm.

For condensate pipings. ..... $k_э$=1.0 mm.

Loss of pressure on friction and in local resistance, and also the throughput capacity of the existing thermal grid/networks taking into account a change of the equivalent roughness in the process of operation are determined on the basis of tests by the formulas:

$$\Delta H = \Delta H_c \frac{G^2}{G_c^2} \text{ kgf/m}^2 \qquad (9.18)$$

$$G = G_c \sqrt{\frac{\Delta H}{\Delta H_c}} \text{ t/h} \qquad (9.19)$$

where

ΔH_c - the total loss of pressure on friction and in local resistance in the existing thermal grid/networks according to the data of measurements in nature in kgf/m²

G_c is a coolant flow rate by which was measured the loss of pressure, in t/h.

9.3. Calculated coolant flow rates.

The winter calculated hourly consumption of network water for hydraulic design of two-funnelled water grid/networks takes as equal to the sum of the calculated winter hourly consumptions of water by the users who, in turn, are equal to the sum of the calculated hourly consumptions of water for heating, the ventilation and the hot water supply, determined by the formulas, given in Table 9.6 and 9.7.

The summer calculated hourly consumption of network water for hydraulic design of two-funnelled water thermal grid/networks is taken equal to the sum of the summer calculated hourly consumptions of water by users for the hot water supply of those determined by the formulas, given in Table 9.8.

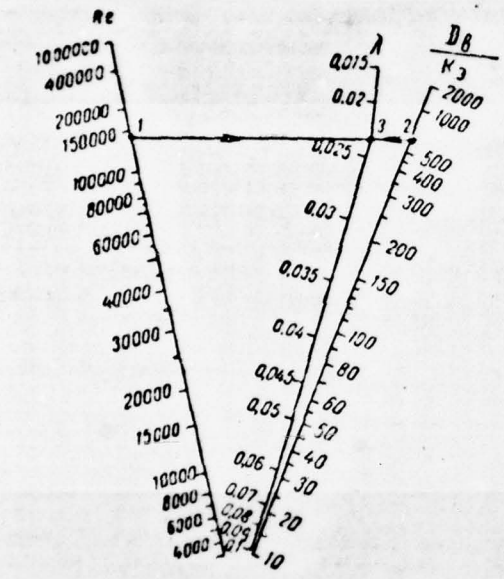


Fig. 9.3

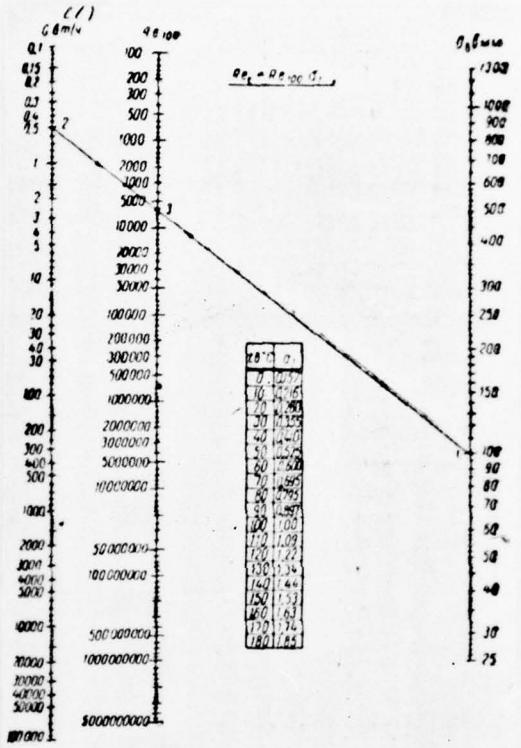


Fig. 9.4

Fig. 9.3. [1]. Nomogram for determining coefficient of friction drag in transition region when $Re<Re_{пр}$

FOOTNOTE [1]. Ye. Z. Rabinovich. Hydraulics. Publishing house Fizmatgiz, 1963. ENDFOOTNOTE.

Fig. 9.4. Nomogram for determining Reynolds number for water (with t = 100°C).

Example. Given D_{e-100} mm; G = 0.5 t/hs; t = 30°C.

Connecting in series points 1 and 2, we find in point 3 $Re_{100}=6250$. We determine $Re_{30}=Re_{100}a_1=6250 \cdot 0{,}355=2215$.

Key: (1). in t/h.

Page 110.

The winter and summer calculated hourly consumptions of network water for hydraulic design of separate thermal grid/networks for hot water supply are received by equal to the sum of the winter or summer calculated hourly consumptions of water users for hot water supply, determined according to the formulas, given in Table 9.9.

Winter calculated hourly consumption pair for hydraulic design of steam lines defines as sum of calculated maximum hourly consumptions pair by users for technological processes, heating, ventilation and hot water supply.

Calculated hourly consumption pair for hydraulic design of the steam lines of the saturated steam they determine, taking into account the additional consumption pair, which goes to the compensation of the condensable vapor.

In the formulas of Table 9.6-9.9:

Q_o; $Q_в$ - the maximum hourly consumptions of heat respectively for heating and ventilation without taking into account of the losses in the pipelines of thermal grid/networks in kcal/h;

$Q_г^{макс}$; $Q_г^{ср}$ - with respect maximum hour and hourly mean heat consumption for everyday hot water supply for the days of the greatest water consumption without taking into account of the losses in the pipelines of thermal grid/networks in kcal/h;

$\left(\frac{Q_г^{ср}}{Q_o}\right)_х$; $\left(\frac{Q_г^{ср}}{Q_o'}\right)$ - the relation of hourly mean heat consumption for hot water supply to maximum hour for the heating, accepted as basis during the construction of the increased

or corrected graph of the temperatures and for a concrete/specific/actual user;

$t_{н.о}; t_{н.п}$ - the calculated temperature of surrounding air respectively for the planning of heating and for the planning of ventilation in deg;

$t_{н}^{-}$ is temperature of surrounding air in salient point of heating graph in deg.

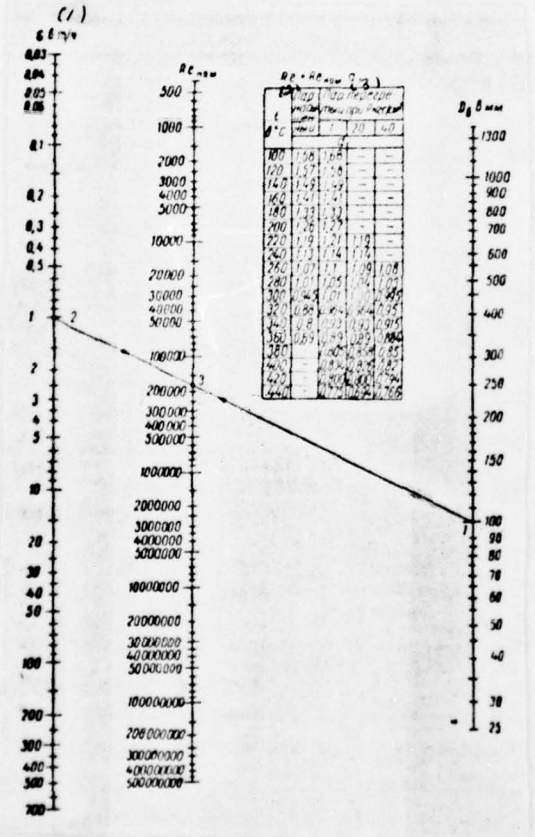


Fig. 9.5

Fig. 9.5. Nomogram for determining Reynolds number for pair.

Example. Is given $D_в = 100$ mm; G = 1 t/h; P = 40 kg/cm²; t = 400°C. Connecting in series points 1 and 2, we find in point 3 $Re_{ном} = 176{,}500$. We determine $Re_{ном} = Re_{ном}$ a_1 = 176,500•0.82 = 145,000.

Key: (1). in t/h. (2). Pairs saturated. (3). Pairs overheated with kg/cm².

Table 9.6. Formulas for determining the calculated hourly consumptions of network water and the specific consumption of network water by users for heating and ventilation.

(1) Системы	(2) Схемы присоединения системы	(3) Расчетная температура наружного воздуха для проектирования отопления и вентиляции в °С	(4) Формула	(5) Удельный расход воды в кг/ч на 1 ккал/ч расчетного расхода тепла при $(\tau_1' - \tau_{2o}')$ в °С		
				95—70	130—70	150—70
(6) Отопление	(7) Непосредственная	$t_{н.о}$	$G_o = \frac{Q_o'}{c(\tau_1' - \tau_{2o}')}$	40	16.7	12.5
	(8) Независимая	$t_{н.о}$	$G_o = \frac{Q_o'}{c[\tau_1' - (\tau_{2o}' + 10)]}$	66.7	20	16.7
(9) Вентиляция	(7) Непосредственная	$t_{н.в} = t_{н.о}$	$G_в = \frac{Q_в'}{c(\tau_1' - \tau_{2o}')}$	40	16.7	12.5
		$t_{н.в}$	$G_в = \frac{Q_в'}{c(\tau_1' - \tau_{2в}')}$ **	53*	22*	17*
	(8) Независимая	$t_{н.в} = t_{н.о}$	$G_в = \frac{Q_в'}{c[\tau_1' - (\tau_{2o}' + 10)]}$	—	20	16.7
		$t_{н.в}$	$G_в = \frac{Q_в'}{c[\tau_1' - (\tau_{2в}' + 10)]}$ **	—	29*	20*

Notes: 1. The numerals, noted by chain wheel, are the averaged at the different temperatures of surrounding air for the planning of ventilation [illegible] consumption of water.

2. With increased graph of temperatures in thermal grid/networks in formulas, noted by two chain wheels, they accept $\tau_1' = \tau_{1o}'$.

Key: (1). Systems. (2). Diagrams of the connection of system. (3). The calculated temperature of surrounding air for the planning of heating and ventilation in °C. (4). Formula. (5). Specific consumption of water in kg/h on 1 kcal/h of the calculated heat consumption when $(\tau_1' - \tau_{2o}')$ in °c. (6). Heating. (7). Direct. (8). Independent. (9). Ventilation.

Pages 111 and 112.

Table 9.7. Formulas for determining the winter calculated hourly consumptions of water by users for hot water supply G_r^p in kg/h for hydraulic design of two-funnelled water thermal grid/networks.

(1) Системы	(2) Расчетный температурный график	(3) Схемы присоединения местных водонагревателей или трубопроводов горячего водоснабжения	(4) При установке местных баков-аккумуляторов для расчета всех участков тепловых сетей	(5) При отсутствии местных баков-аккумуляторов	
				(6) для расчета магистральных и распределительных тепловых сетей	(7) для расчета ответвлений к отдельным зданиям
(8) Закрытая	(9) Отопительный	(10) Параллельная	$\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_3''\right)}$	$1{,}3-1{,}4\,\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_3''\right)}$	$\frac{Q_r^{макс}}{c\left(\tau_1'' - \tau_3''\right)}$
		(11) Предвключенная	$\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)}$	$1{,}3-1{,}4\,\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)}$	$1{,}3-1{,}4\,\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)}$
		(12) Смешанная двухступенчатая	$\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)} \cdot \frac{t_r - t_n}{t_r - t_{x.з}}$	$1{,}2-1{,}3\,\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)} \times \frac{t_r - t_n}{t_r - t_{x.з}}$	$\frac{Q_r^{макс}}{c\left(\tau_1'' - \tau_{2o}''\right)} \cdot \frac{t_r - t_n}{t_r - t_{x.з}}$
		(13) Последовательная двухступенчатая			$1{,}2-1{,}3\,\frac{Q_r^{cp}}{c\left(\tau_1'' - \tau_{2o}''\right)} \times \frac{t_r - t_n}{t_r - t_{x.з}}$

Table 9.7 (con't)

(8) Закрытая	(14) Повышенный	(10) Параллельная	$\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{3}\right)}$	$1.3-1.4\,\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{3}\right)}$	$\frac{Q_r^{макс}}{c\left(\tau''_{1n}-\tau''_{3}\right)}$
		(11) Предвключенная	$\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}$	$1.3-1.4\,\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}$	$1.3-1.4\,\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}$
		(12) Смешанная двухступенчатая	$\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}\cdot\frac{t_r-t_n}{t_r-t_{x.з}}$	$1.2-1.3\,\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}\times\frac{t_r-t_n}{t_r-t_{x.з}}$	$\frac{Q_r^{макс}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}\cdot\frac{t_r-t_n}{t_r-t_{x.з}}$
		(15) Последовательная двухступенчатая: (16а) для потребителей при $\left(\frac{Q_r^{cp}}{Q'_o}\right)<\left(\frac{Q_r^{cp}}{Q'_o}\right)_x$	0	0	$1.2-1.3\,\frac{Q_r^{cp}}{c\left(\tau''_{1n}-\tau''_{2o}\right)}\times\frac{t_r-t_n}{t_r-t_{x.з}}$
		(16б) для потребителей при $\left(\frac{Q_r^{cp}}{Q'_o}\right)>\left(\frac{Q_r^{cp}}{Q'_o}\right)_x$	$\frac{Q'_o}{c\left(\tau''_{1n}-\tau''_{2o}\right)}\cdot\frac{t_r-t_n}{t_r-t_{x.з}}\times\left[\frac{Q_r^{cp}}{Q'_o}-\left(\frac{Q_r^{cp}}{Q'_o}\right)_x\right]$	$0.6-0.8\,\frac{Q_r^{cp}}{c\left(t_r-t_{x.з}\right)}$	
(9) Открытая	(19) Отопительный: Подающий		$\frac{Q_r^{cp}}{c\left(t_r-t_{x.з}\right)}$	$0.6-0.8\,\frac{Q_r^{cp}}{c\left(t_r-t_{x.з}\right)}$	$\frac{Q_r^{макс}}{c\left(t_r-t_{x.з}\right)}$
		(21) Обратный	0		
	(18) Скорректированный: (20) Подающий и обратный	(20а) для потребителей при $\left(\frac{Q_r^{cp}}{Q'_o}\right)<\left(\frac{Q_r^{cp}}{Q'_o}\right)_x$	0	0	
		(22) Подающий: (22б) для потребителей при $\left(\frac{Q_r^{cp}}{Q'_o}\right)>\left(\frac{Q_r^{cp}}{Q'_o}\right)_x$	$\frac{Q'_o}{c\left(t_r-t_{x.з}\right)}\times\left[\frac{Q_r^{cp}}{Q'_o}-\left(\frac{Q_r^{cp}}{Q'_o}\right)_x\right]$	$0.6-0.8\,\frac{Q'_o}{c\left(t_r-t_{x.з}\right)}\times\left[\frac{Q_r^{cp}}{Q'_o}-\left(\frac{Q_r^{cp}}{Q'_o}\right)_x\right]$	

Key: (1). system. (2). Design temperature chart. (3). Diagrams of the connection of local water heaters or pipelines of hot water supply. (4). During the setting up of local storage tanks for the calculation of all sections of thermal grid/networks. (5). In the absence of local storage tanks. (6). for the calculation of main-line and distributive thermal grid/networks. (7). for the calculation of branches to separate buildings. (8). Closed. (9). Heating. (10). Parallel. (11). Connected in series. (12). The mixed is two-stage. (13). Consecutive is two-stage. (14). Increased. (15). Consecutive is two-stage. (16). for users with. (17). Opened. (18). Corrected. (19). Feed. (20). Feeding and reverse/inverse. (21). Reverse/inverse. (22). for users with.

FOOTNOTE *. For return line the consumption is equal to zero. ENDFOOTNOTE.

$\tau_1'; \tau_{2o}'$ - temperature of network water on heating graph when $t_{н.о}$ respectively in delivery pipe and in return line from heating system in deg;

$\tau_1'; \tau_{2в}'$ - the temperature of network water on heating graph when $t_{н.в}$ respectively in delivery pipe and in return line from ventilation system in deg;

$\tau_{1н}'$ is temperature of network water in delivery pipe on the increased or corrected graph when $t_{н.в}$ in deg;

$\tau_1''; \tau_{2o}''$ is temperature of network water in salient point of heating graph when $t_н''$ respectively in delivery pipe and in return line from heating system in deg;

$\tau_{1н}''$ - the temperature of network water in delivery pipe on the increased graph in salient point of graph when $t_н''$ in deg;

τ_3'' is temperature of network water after the in parallel connected water heater of hot water supply in salient point of graph when $t_н''$ in deg;

τ_1' - the temperature of network water in delivery pipe

in summer period in deg;

τ_3' - the temperature of network water after local water heater in summer period in deg;

$t_{x.3}$, $t_{x.s}$ - the temperature of cold tap water respectively in winter and summer period in deg;

t_r - the temperature of the hot water, which enters the local system of hot water supply, in deg;

t_n is temperature of tap water after the water heater of first stage in salient point of graph; is recommended to accept $t_n = (\tau_{2o}'' - 5)$ °C;

c - the heat capacity of water in kcal/kg deg are allowed of equal to 1 kcal/kg deg.

The consumption of the condensable vapor on this section of steam line is determined from the formula

$$G_n = \frac{q_{y.s}(t_{cp} - t_o)\,l}{r} 10^{-3} \text{t/h} \qquad (9.20)$$

where r is heat of vaporization in kcal/kg, the

corresponding to mean pressure pair on calculated section by length 1 m;

t_{cp} - mean temperature is pair on the designed section in °C;

t_0 - an ambient temperature in deg is accepted: in the impassable channels t_0 = 0°C; in the passage channels t_0 = 40°C; with above-grade packing $t_0 = t_{н.о}$ °C;

$q_{уд}$ is the specific heat loss by the isolated/insulated steam line taking into account the heat losses by reinforcement, compensators and supports in kcal/m h deg; it is accepted according to Table 9.10.

Mean temperature pair on the designed section is determined from the formula

$$t_{cp} = \frac{t_1 + t_2}{2} °C, \qquad (9.21)$$

where t_1, t_2 - temperature is pair in the beginning and at the end of the calculated section in deg.

Calculated hourly consumption pair on the designed section of the steam line of the saturated steam determine from the formula

$$G_p = G + 0{,}5\,G_п + \Sigma G_п \text{ т/ч} \qquad (9.22)$$

where G - calculated consumption pair on the section of steam line without taking into account of consumption pair for the compensation of the losses in t/h;

G_n-consumption pair for the compensation of the losses on the designed section in t/h;

ΣG_n - consumption pair for the compensation of losses of heat by the sections of steam line, arrange/located between the end user and the designed section, in t/h.

Table 9.8. formula for determining the summer calculated hourly consumptions of network water by users for hot water supply $G_г^р$ in kg/h for hydraulic design of two-funnelled water thermal grid/networks.

(1) Системы		(2) При установке местных баков-аккумуляторов для расчета всех участков тепловых сетей	(3) При отсутствии местных баков-аккумуляторов			
			(4) для городов и населенных мест		(5) для промышленных предприятий	
			(6) для расчета магистральных и распределительных тепловых сетей	(7) для расчета ответвлений к отдельным зданиям	(6) для расчета магистральных и распределительных тепловых сетей	(7) для расчета ответвлений к отдельным зданиям
(8) Закрытая		$\frac{0{,}65Q_г^{ср}}{c\left(\tau_1^л-\tau_3^л\right)}$	$\frac{1{,}3Q_г^{ср}}{c\left(\tau_1^л-\tau_3^л\right)}$	$\frac{0{,}65Q_г^{макс}}{c\left(\tau_1^л-\tau_3^л\right)}$	$\frac{Q_г^{ср}}{c\left(\tau_1^л-\tau_3^л\right)}$	$\frac{Q_г^{макс}}{c\left(\tau_1^л-\tau_3^л\right)}$
(9) Открытая	(10) подающий трубопровод	$\frac{0{,}65Q_г^{ср}}{c\left(t_г-t_{х.л}\right)^*}$	$\frac{1{,}3Q_г^{ср}}{c\left(t_г-t_{х.л}\right)}$	$\frac{0{,}65Q_г^{макс}}{c\left(t_г-t_{х.л}\right)}$	$\frac{Q_г^{ср}}{c\left(t_г-t_{х.з}\right)}$	$\frac{Q_г^{макс}}{c\left(t_г-t_{х.з}\right)}$
	(11) обратный трубопровод	(12) 10 % от соответствующего расчетного расхода сетевой воды в подающем трубопроводе				

Key: (1). Systems. (2). During the setting up of local storage tanks for the calculation of all sections of thermal grid/networks. (3). In the absence of local storage tanks. (4). for cities and the populated places. (5). for industrial enterprises. (6). for the calculation of main-line

and distributive thermal grid/networks. (7). for the calculation of branches to separate buildings. (8). Closed. (9). Opened. (10). delivery pipe. (11). return line. (12). from the appropriate calculated consumption of network water in delivery pipe.

FOOTNOTE *. For industrial enterprises in the formula, noted by chain wheel, instead of coefficient of 0.65 is accepted the coefficient, equal to one.

Table 9.9. Formulas for determining the winter and summer calculated hourly consumptions of network water by users G_r^p in kg/h for hydraulic design of separate thermal grid/networks for hot water supply.

(1) Трубопроводы		(2) При установке местных баков-аккумуляторов для расчета всех участков тепловых сетей	(3) При отсутствии местных баков-аккумуляторов			
			(4) для городов и населенных мест		(5) для промышленных предприятий	
			(6) для расчета магистральных и распределительных тепловых сетей	(7) для расчета ответвлений к отдельным зданиям	(6) для расчета магистральных и распределительных тепловых сетей	(7) для расчета ответвлений к отдельным зданиям
(8) Подающий	(9) зимний расчетный расход сетевой воды	$\frac{Q_r^{ср}}{c(t_г - t_{х.з})}$	$\frac{2Q_r^{ср}}{c(t_г - t_{х.з})}$	$\frac{Q_r^{макс}}{c(t_г - t_{х.з})}$	$\frac{Q_r^{ср}}{c(t_г - t_{х.з})}$	$\frac{Q_r^{макс}}{c(t_г - t_{х.з})}$
	(10) летний расчетный расход сетевой воды	$\frac{0{,}65Q_r^{ср*}}{c(t_г - t_{х.л})}$	$\frac{1{,}3Q_r^{ср}}{c(t_г - t_{х.л})}$	$\frac{0{,}65Q_r^{макс}}{c(t_г - t_{х.л})}$	$\frac{Q_r^{ср}}{c(t_г - t_{х.з})}$	$\frac{Q_r^{макс}}{c(t_г - t_{х.з})}$
(11) Циркуляционный		(12) 10 % от соответствующего расчетного расхода сетевой воды в подающем трубопроводе				

Notes: 1. For industrial enterprises in the formula, noted by chain wheel, instead of coefficient of 0.65 is accepted the coefficient, equal to one.

2. Additional consumption of water for recirculation in

delivery pipe is not considered.

Key: (1). Pipelines. (2). During the setting up of local storage tanks for the calculation of all sections of thermal grid/networks. (3). In the absence of local storage tanks. (4). for cities and the populated places. (5). for industrial enterprises. (6). for the calculation of main-line and distributive thermal grid/networks. (7). for the calculation of branches to separate buildings. (8). Feeding. (9). the winter calculated consumption of network water. (10). the summer calculated consumption of network water. (11). Circulation. (12). from the appropriate calculated consumption of network water in delivery pipe.

Table 9.10. Specific losses of heat 1 m of the isolated/insulated steam line taking into account the additional heat losses by reinforcement, supports and compensators $q_{уд}$ in kcal/m h deg with a difference in the temperatures between the temperature of the vapor and the environment in 1 deg.

(1) Наружный диаметр трубы $D_н$ в мм	(2) Надземная прокладка			(3) Прокладка в непроходных каналах			(4) Прокладка в тоннелях		
	(5) температура пара в *град*								
	200	250—300	350—450	200	250—300	350	200	250—300	350—450
32	0,41	0,41	0,41	0,4	0,39	0,39	0,45	0,44	0,42
45	0,47	0,46	0,46	0,46	0,46	0,45	0,51	0,5	0,48
57	0,52	0,51	0,51	0,5	0,49	0,48	0,55	0,54	0,51
76	0,57	0,57	0,56	0,55	0,55	0,54	0,61	0,59	0,57
89	0,62	0,61	0,59	0,60	0,58	0,57	0,64	0,62	0,6
108	0,68	0,66	0,65	0,65	0,64	0,62	0,7	0,67	0,65
133	0,74	0,72	0,71	0,71	0,69	0,68	0,79	0,75	0,71
159	0,8	0,78	0,77	0,77	0,75	0,74	0,88	0,83	0,77
219	0,94	0,93	0,91	0,9	0,89	0,87	1,03	0,98	0,92
273	1,07	1,05	1,01	1,03	1,01	0,97	1,14	1,09	1,02
325	1,2	1,17	1,13	1,15	1,12	1,09	1,25	1,19	1,12
377	1,32	1,27	1,22	1,28	1,22	1,18	1,37	1,3	1,21
426	1,34	1,3	1,22	1,29	1,22	1,17	1,37	1,33	1,2
478	1,44	1,37	—	1,39	1,31	1,25	1,47	1,39	—
529	1,51	1,46	—	1,45	1,41	1,33	1,58	1,48	—
630	1,69	1,61	—	1,62	1,55	1,47	1,82	1,7	—
720	1,83	1,75	—	1,75	1,68	1,6	2,02	1,86	—
820	2,03	1,94	—	1,95	1,87	1,78	2,26	2,08	—
920	2,28	2,14	—	2,18	2,06	1,95	2,48	2,27	—
1020	2,51	2,37	—	2,40	2,28	2,14	2,66	2,46	—

Notes: 1. When determining the specific losses, the ambient temperature is accepted: for above-grade packing the average annual temperature of surrounding air +5° C; for packing in impassable channels the average annual temperature of soil on the axis of the laying of steam line +5°C; for packing in passage channels the temperature of air in channel +40°C.

2. Additional heat losses by reinforcement, supports and compensators are taken into account by coefficients: for main-line thermal grid/networks, laid in tunnels and channels, 1, 15; with above-grade packing 1.2; for distributive thermal grid/networks and branches to separate buildings, laid in tunnels and channels, 1.25; with above-grade packing 1.3.

Key: (1). Outside diameter of tube D_H in mm. (2). Above-grade packing. (3). Packing in impassable channels. (4). Packing in tunnels. (5). temperature is pair in deg.

Page 115.

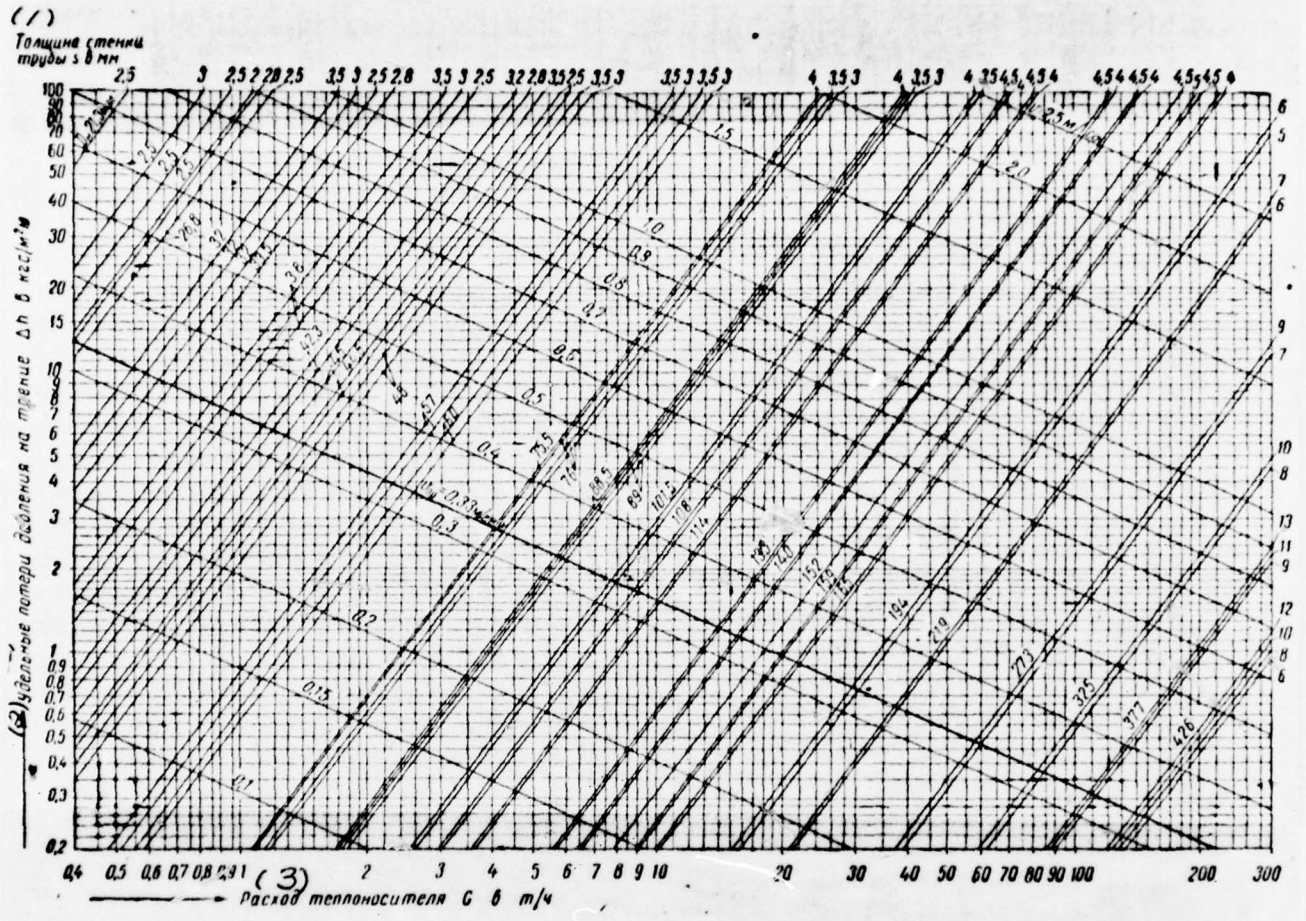


Fig. 9.6.

Fig. 9.6. Nomogram for hydraulic design of pipelines with $k_э$=0,5 mm and γ = 958 kg/m³ with coolant flow rate from 0.4 to 300 m/h. Heavy line designated the maximum speed $v_{пр}$ = 0,33 m/s, corresponding to the boundary/interface between the transfer and quadratic region.

Key: (1). The wall thickness of tube s in mm. (2). Specific losses of pressure on friction Δh in kgf/m² m. (3). Coolant flow rate G in t/h.

Page 116.

The winter calculated hourly consumptions of condensate for hydraulic design of condensate pipings determine according to a maximum hour quantity of the condensate returned by users or by the separate pumping of the return of condensate. The return of condensate from the local heating systems, ventilation and hot water supply, workers on vapor, for the calculation of condensate pipings is accepted in size/dimension of 100o/o of consumption pair. The return of condensate from technological processes is accepted according to the project of the local system of technological steam lines.

9.4. Hydraulic design of the pipelines of water thermal grid/networks.

Hydraulic design of the pipelines of water thermal grid/networks is performed on the nomograms of Fig. 9.6 and 9.7 or of Table 9.11.

The values of the equivalent lengths of local resistance are accepted according to Table 9.12 and 9.13.

During the compilation of tables and nomograms, it is accepted: the temperature of water t = 100°C, the specific gravity/weight of water γ = 958.4 kg/m³, the equivalent roughness of tubes $k_э = 0.5$ mm and the kinematic viscosity of water $\nu = 0.295 \cdot 10^{-6}$ m²/s.

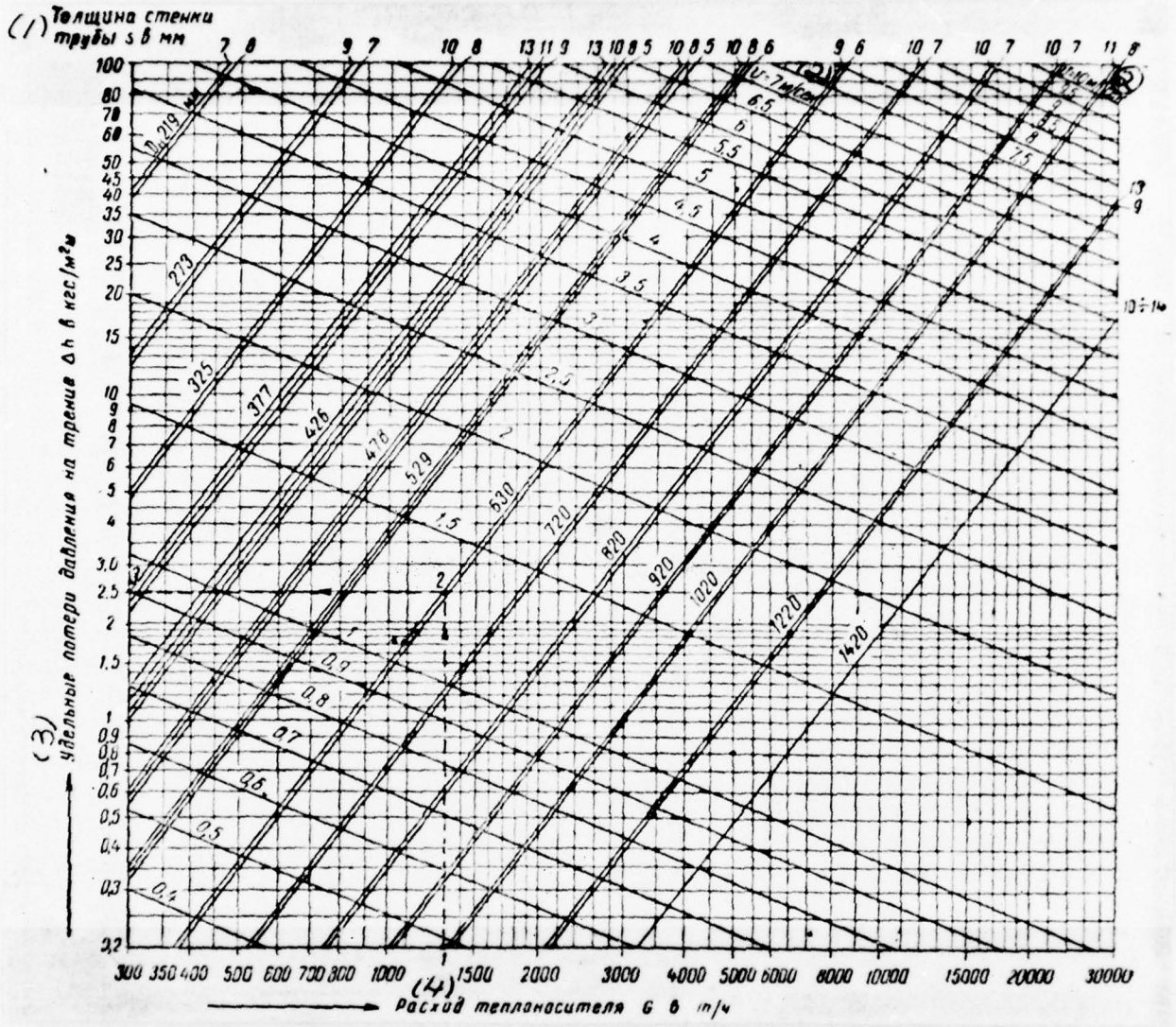

(1) Толщина стенки трубы s в мм
(2) v=1 м/сек
(3) Удельные потери давления на трение Δh в кгс/м²м
(4) Расход теплоносителя G в т/ч
Dн 219
273
325
377
426
478
529
630
720
820
920
1020
1220
1420

Fig. 9.7

Fig. 9.7. Nomogram for hydraulic design of pipelines with $\Delta_э$=0,5 mm and γ = 958 kg/m³ with coolant flow rate from 300 to 30,000 t/hs. Example. It is given to G = 1300 t/hs; $D_н$=630 mm; s = 9 mm. We find in point 2 v = 1.3 m/s, and in point 3 Δh = 2.45 kgf/m² m.

Key: (1). The wall thickness of tube s in mm. (2). m/s. (3). Specific padres of pressure on friction Δh in kgf/m² m. (4). Coolant flow rate G t/h.

Pages 117-125.

At the values of specific gravity/weights, equivalent roughnesses and tube bores, which differ from the taken during compilation tables and nomograms, value Δh, v and G, obtained the tables and nomogram, recount by the following formulas:

a) at the values of specific gravity/weights $\gamma' \neq \gamma$:

$$\Delta h' = \Delta h \frac{\gamma}{\gamma'} \text{ kgf/m}^2 \text{ m} \qquad (9.23)$$

$$v' = v \frac{\gamma}{\gamma'} \text{ m/s} \qquad (9.24)$$

b) at the values of the equivalent roughnesses $k'_э \neq k_э$ tentatively:

$$\Delta h' = \Delta h \sqrt[4]{\frac{k'_э}{k_э}} \text{ kgf/m}^2 \quad \text{m}; \quad (9.25)$$

$$l'_э = l_э \sqrt[4]{\frac{k_э}{k'_э}} \text{ m} \quad (9.26)$$

Value $\sqrt[4]{\frac{k'_э}{k_э}}$ and $\sqrt[4]{\frac{k_э}{k'_э}}$ they equate $\sqrt{\frac{k_A}{k_B}}$ are determined according to Table 9.14.

For a conversion from tables and the nomograms, comprised at the values of equivalent roughness, $k_э = 0{,}5$ mm:

$$\Delta h' = 3\Delta h \text{ kgf/m}^2 \quad \text{m}; \quad (9.27)$$

$$l'_э = \frac{1}{\beta} l_э \text{ m} \quad (9.28)$$

where β is the coefficient, taken on Table 9.15;

c) at the values of tube bores $D'_э \neq D_э$:

$$\Delta h' = \Delta h \left[\frac{D_э}{D'_э}\right]^{5{,}25} \text{ kgf/m}^2 \quad \text{m}; \quad (9.29)$$

$$v' \sim v\left[\frac{D_н}{D'_н}\right]^2 \text{м/с;} \qquad (9.30)$$

$$l'_т \sim l_т\left[\frac{D_н}{D'_н}\right]^{1.25} \text{м.} \qquad (9.31)$$

For the facilitation of calculations Fig. 9.8 gives graph for determining the values $\left[\frac{D_н}{D'_н}\right]$ tc degrees of 5.25; 2 and 1.25.

At the calculated coolant flow rates, coming out beyond the limits of tabular values, it is possible to find values Δh and v from these tables for the conditional coolant flow rate, increased or reduced in n once:

if conditional load it is increased in n once against that which is required, then the corresponding to it tabular values v and Δg necessary to decrease: the rate in n once, and frictional resistance in n² once;

if the conditional load is reduced n times, then value v and Δh it is necessary to increase: the rate in n

once, and frictional resistance in n^2 once.

Value n is most simple accepted equal to 10.

For the intermediate values of the coolant flow rates of the value of velocities and specific losses of pressure, they determine by linear interpolation.

Table 9.11. Table for hydraulic calculations of conduits with $k_э = 0{,}5$ mm and $\gamma = 958{,}4$ Kg/m^3.

$D_н \times s$ в (1) мм	32×2.5		38×2.5		44.5×2.5		45×2.5		57×3.5	
G в (2) т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
0.2	0 1	0,95								
0.22	0.11	1.14								
0.24	0.17	1.35								
0.26	0.13	1.59								
0.28	0.14	1.82								
0.3	0.15	2.08	0.1	0.72						
0.32	0.16	2.37	0.11	0.81						
0.34	0.17	2.71	0.12	0.92						
0.36	0.18	2.97	0.12	1.03						
0.38	0.19	3.3	0.13	1.15						
0.4	0.2	3.65	0 14	1.26						
0.42	0.21	4	0.14	1.37						
0.44	0.22	4.38	0.15	1.52	0,1	0.59	0.1	0.55		
0.46	0.23	4.75	0.16	1.66	0.11	0.64	0.11	0.6		
0.48	0.24	5.15	0.16	1.82	0.11	0.69	0.11	0.65		
0.5	0.25	5.55	0.17	1.95	0.12	0.76	0.12	0.7		
0.55	0.28	6.66	0.19	2.35	0.13	0.91	0.13	0.85		
0.6	0.3	7.85	0.2	2.8	0.14	1.07	0.14	1.01		
0.65	0.33	8.19	0.22	3.26	0.15	1.27	0.15	1.18		
0.7	0.35	10.7	0.24	3.77	0.17	1.46	0.16	1.37	0.1	0.44
0.75	0.38	12.3	0.25	4.31	0.18	1.67	0.17	1.57	0.11	0.5
0.8	0.41	14	0.27	4.86	0.19	1.9	0.18	1.77	0.12	0.57
0.85	0.43	15.8	0.29	5.45	0.2	2.13	0,2	2	0.13	0.65
0.9	0.46	17.7	0.31	6.08	0.21	2 38	0.21	2.22	0.13	0.72
0.95	0.48	19.7	0.32	6.73	0.22	2.64	0.22	2.48	0.14	0.8
1	0.51	21.9	0.34	7.45	0,24	2,91	0.23	2.72	0.15	0.88
1.05	0.53	24.1	0,36	8.21	0.25	3.2	0.24	2.99	0.16	1.07
1.1	0.56	26.5	0.37	9.01	0 26	3.51	0.25	3.29	0.16	1.05
1.15	0.58	28.9	0.39	9.85	0.27	3.82	0.27	3.58	0.17	1.14
1.2	0.61	32	0.41	10.7	0.28	4.15	0.28	3.87	0.18	1.24

$D_н \times s$ в (1) мм	32×2.5		38×2.5		44.5×2.5		45×2.5		57×3.5		76×3.5	
G в (2) т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
1.25	0.63	34.2	0,42	11.6	0.3	4.48	0.29	4.2	0.18	1.34		
1.3	0.66	37	0.44	12.6	0.31	4.83	0,3	4.51	0.19	1.44	0.1	0.27
1.35	0.68	39.9	0.46	13.6	0.32	4.18	0.31	4.86	0.2	1.55	0.1	0.29
1.4	0.71	42.9	0.47	14.6	0.33	5.57	0.32	5.21	0.21	1.67	0.11	0.31
1.45	0.73	46	0.49	15.7	0.34	5.98	0.33	5.59	0.21	1.78	0.11	0.33
1.5	0.76	49.2	0,51	16.8	0.36	6.4	0.35	5.98	0.22	1.91	0.12	0.36
1.55	0.79	52.6	0.53	17.9	0.37	6.83	0.36	6.38	0.23	2.02	0.12	0.38
1.6	0.81	56	0.54	19.1	0.38	7.28	0.37	6.8	0 24	2.14	0.12	0.4
1.65	0.84	59.6	0.56	20,3	0,39	7,74	0.38	7.23	0.24	2.26	0 13	0.43
1.7	0.86	63,2	0.58	21.5	0.4	8 21	0,39	7.68	0.25	2.4	0,13	0.46
1.75	0.89	67	0.59	22.8	0.41	8.7	0,4	8.14	0.26	2.53	0,14	0.48
1.8	0.91	70.9	0.61	24,1	0,43	9.21	0,42	8.61	0.27	2.66	0,14	0.51
1.85	0.94	74.9	0.63	25.5	0.44	9.73	0.43	9.09	0.27	2.81	0.14	0.53
1.9	0.96	79	0.64	26.9	0.45	10.3	0.44	9.59	0.28	2.96	0.15	0.56
1.95	0.99	83.2	0.66	28.3	0.46	10.8	0,45	10.1	0.29	3.1	0,15	0.59
2	1,01	87.5	0.68	29.8	0,47	11.4	0.46	10.6	0,3	3.25	0.16	0.62

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ в мм (1)	32×2.5		38×2.5		44.5×2.5		45×2.5		57×3.5		76×3.5	
G в т/ч (2)	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
2,1	1,06	96,5	0,71	32,8	0,5	12,5	0,48	11,7	0,31	3,55	0,16	0,68
2,2	1,11	105,9	0,75	36	0,52	13,8	0,51	12,9	0,33	3,99	0,17	0,75
2,3			0,78	39,4	0,54	15	0,53	14,1	0,34	4,27	0,18	0,81
2,4			0,81	42,9	0,57	16,4	0,55	15,3	0,35	4,64	0,19	0,88
2,5			0,85	46,5	0,59	17,8	0,58	16,6	0,37	5,04	0,19	0,96
2,6			0,88	50,3	0,62	19,2	0,6	18	0,38	5,45	0,2	1,03
2,7			0,92	54,3	0,64	20,7	0,62	19,4	0,4	5,88	0,21	1,11
2,8			0,95	58,4	0,66	22,3	0,65	20,8	0,41	6,32	0,22	1,15
2,9			0,98	62,6	0,69	23,9	0,67	22,3	0,43	6,78	0,22	1,25
3			1,02	67	0,71	25,6	0,69	23,9	0,44	7,26	0,23	1,35
3,1			1,05	71,6	0,74	27,3	0,72	25,5	0,46	7,75	0,24	1,45
3,2			1,09	76,3	0,76	29,1	0,74	27,2	0,47	8,26	0,25	1,53
3,3			1,12	81,1	0,78	31	0,76	28,9	0,49	8,78	0,26	1,62
3,4			1,15	86,1	0,8	32,9	0,78	30,7	0,5	9,32	0,26	1,73

$D_н \times s$ в мм (1)	44,5×2.5		45×2.5		57×3,5		76×3,5		89×3,5		108×4		133×4	
G в т/ч (2)	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
3,5	0,83	34,8	0,81	32,6	0,52	9,88	0,27	1,82	0,19	0,71	0,13	0,27		
3,6	0,85	36,8	0,83	34,4	0,53	10,4	0,28	1,92	0,2	0,75	0,13	0,28		
3,7	0,88	38,9	0,85	36,4	0,55	11	0,29	2,02	0,2	0,79	0,14	0,29		
3,8	0,9	41	0,88	38,4	0,56	11,6	0,29	2,13	0,21	0,83	0,14	0,31		
3,9	0,92	43,2	0,9	40,4	0,58	12,3	0,3	2,22	0,21	0,88	0,14	0,33		
4	0,95	45,5	0,92	42,5	0,59	12,9	0,31	2,33	0,22	0,92	0,15	0,34		
4,2	0,99	50,1	0,97	46,9	0,62	14,2	0,33	2,48	0,23	1,01	0,16	0,38		
4,4	1,04	55	1,02	51,4	0,65	15,6	0,34	2,81	0,24	1,11	0,16	0,41	0,1	0,13
4,6	1,09	60,1	1,06	56,2	0,68	17,1	0,36	3,07	0,25	1,21	0,17	0,45	0,11	0,14
4,8	1,14	65,5	1,11	61,2	0,71	18,6	0,37	3,34	0,26	1,32	0,18	0,49	0,11	0,15
5	1,18	71,1	1,15	66,4	0,74	20,2	0,39	3,62	0,27	1,43	0,18	0,53	0,12	0,17
5,2	1,23	76,9	1,2	71,9	0,77	21,8	0,4	3,92	0,29	1,54	0,19	0,57	0,12	0,18
5,4	1,28	82,9	1,25	77,5	0,8	23,5	0,42	4,23	0,3	1,66	0,2	0,61	0,13	0,19
5,6	1,33	89,1	1,29	83,3	0,83	25,7	0,43	4,54	0,31	1,78	0,21	0,65	0,13	0,2
5,8	1,37	95,6	1,34	89,4	0,86	27,1	0,45	4,87	0,32	1,91	0,21	0,7	0,14	0,22
6	1,42	102,3	1,39	95,7	0,89	29	0,47	5,22	0,33	2,04	0,22	0,75	0,14	0,23
6,2			1,43	102,1	0,92	31	0,48	5,57	0,34	2,22	0,23	0,8	0,15	0,25
6,4					0,95	33	0,5	5,94	0,35	2,37	0,24	0,85	0,15	0,26
6,6					0,98	35,1	0,51	6,31	0,36	2,52	0,24	0,9	0,16	0,28
6,8					1	37,3	0,53	6,7	0,37	2,68	0,25	0,95	0,16	0,31
7					1,03	39,5	0,54	7,1	0,38	2,84	0,26	1,01	0,17	0,32
7,5					1,11	45,4	0,58	8,15	0,41	3,26	0,28	1,15	0,18	0,37
8					1,18	51,6	0,62	9,27	0,44	3,7	0,3	1,3	0,19	0,42
8,5					1,26	58,3	0,66	10,5	0,47	4,18	0,31	1,46	0,2	0,47
9					1,33	65,3	0,7	11,7	0,49	4,69	0,33	1,64	0,21	0,52
9,5					1,4	72,8	0,74	13,1	0,52	5,22	0,35	1,82	0,22	0,58
10					1,48	80,6	0,78	14,5	0,55	5,79	0,37	2,02	0,24	0,64
10,5					1,55	88,9	0,81	16	0,58	6,38	0,39	2,22	0,25	0,7
11					1,63	97,6	0,85	17,5	0,6	7	0,41	2,44	0,26	0,77
11,5					1,7	106,6	0,89	19,2	0,63	7,65	0,42	2,67	0,27	0,84

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ в мм (1)	76×3,5		89×3,5		108×4		133×4		152×4,5		159×4,5		194×6		194×5	
G в т/ч (2)	v в м/сек (3)	Δh в кгс/м² м (4)	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh
12	0,93	20,9	0,66	8,33	0,44	2,91	0,28	0,9	0,22	0,46	0,2	0,36				
12,5	0,97	22,6	0,69	9,04	0,46	3,15	0,3	0,98	0,23	0,49	0,21	0,39				
13	1,08	24,5	0,71	9,78	0,48	3,41	0,31	1,06	0,23	0,53	0,21	0,42				
13,5	1,05	26,4	0,74	10,5	0,5	3,68	0,32	1,13	0,24	0,57	0,22	0,45				
14	1,09	28,4	0,77	11,3	0,52	3,96	0,33	1,21	0,25	0,61	0,23	0,48				
14,5	1,12	30,5	0,8	12,2	0,54	4,24	0,34	1,3	0,26	0,66	0,24	0,51				
15	1,16	32,6	0,82	13	0,55	4,54	0,35	1,39	0,27	0,69	0,25	0,55	0,17	0,2	0,16	0,19
16	1,24	37,1	0,88	14,8	0,59	5,17	0,38	1,58	0,29	0,79	0,26	0,62	0,18	0,23	0,17	0,21
17	1,32	41,9	0,93	16,7	0,63	5,83	0,4	1,79	0,31	0,88	0,28	0,69	0,19	0,26	0,19	0,24
18	1,4	46,9	0,99	18,8	0,66	6,54	0,43	2,01	0,33	0,99	0,3	0,77	0,2	0,29	0,2	0,27
19	1,47	52,3	1,04	20,9	0,7	7,29	0,45	2,23	0,34	1,1	0,31	0,85	0,21	0,32	0,21	0,3
20	1,55	58	1,1	23,2	0,74	8,08	0,47	2,48	0,36	1,22	0,33	0,95	0,22	0,35	0,22	0,33
21	1,63	63,9	1,15	25,5	0,78	8,9	0,5	2,73	0,38	1,34	0,34	1,04	0,23	0,39	0,23	0,36
22	1,71	70,1	1,21	28	0,81	9,77	0,52	3	0,4	1,47	0,36	1,14	0,25	0,42	0,24	0,4
23	1,78	76,7	1,26	30,6	0,85	10,7	0,54	3,27	0,42	1,61	0,38	1,25	0,26	0,46	0,25	0,43
24	1,86	83,5	1,32	33,3	0,89	11,6	0,57	3,57	0,43	1,75	0,39	1,36	0,27	0,5	0,29	0,48
25	1,94	90,6	1,37	36,2	0,92	12,6	0,59	3,87	0,45	1,9	0,41	1,47	0,28	0,54	0,27	0,51
26	2,02	98	1,43	39,1	0,96	13,6	0,62	4,19	0,47	2,05	0,43	1,6	0,29	0,59	0,28	0,55
27	2,09	105,6	1,48	42,2	1	14,7	0,64	4,51	0,49	2,22	0,44	1,72	0,4	0,63	0,29	0,59
28			1,54	45,4	1,03	15,8	0,66	4,85	0,51	2,38	0,46	1,85	0,31	0,68	0,31	0,64
29			1,59	48,7	1,07	17	0,69	5,21	0,52	2,56	0,48	1,99	0,32	0,72	0,32	0,68
30			1,65	52,1	1,11	18,2	0,71	5,57	0,54	2,73	0,49	2,12	0,33	0,77	0,33	0,73
31			1,7	55,6	1,15	19,4	0,73	5,95	0,56	2,92	0,51	2,27	0,35	0,82	0,34	0,77
32			1,76	59,3	1,18	20,7	0,76	6,34	0,58	3,11	0,53	2,42	0,36	0,87	0,35	0,82
33			1,81	63	1,22	22	0,78	6,74	0,6	3,31	0,54	2,57	0,37	0,93	0,36	0,87
34			1,87	66,9	1,26	23,3	0,8	7,16	0,61	3,51	0,56	2,73	0,38	0,98	0,37	0,93
35			1,92	70,9	1,29	24,7	0,83	7,58	0,63	3,72	0,57	2,89	0,39	1,04	0,38	0,98
36			1,98	75	1,33	26,2	0,85	8,02	0,65	3,94	0,59	3,06	0,4	1,1	0,39	1,04
37			2,03	79,2	1,37	27,6	0,87	8,48	0,67	4,16	0,61	3,23	0,41	1,16	0,4	1,1
38			2,09	83,6	1,4	29,2	0,9	8,94	0,69	4,39	0,62	3,41	0,42	1,23	0,41	1,16

$D_н \times s$ в мм (1)	108×4		133×4		152×4,5		159×4,5		194×6		194×5		219×7		219×6		273×8		273×7	
G в т/ч (2)	v в м/сек (3)	Δh в кгс/м² м (4)	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh	v	Δh
39	1,44	30,7	0,92	9,42	0,7	4,62	0,64	3,59	0,43	1,29	0,43	1,22	0,34	0,69	0,34	0,66	0,22	0,22	0,21	0,22
40	1,48	32,3	0,95	9,91	0,72	4,86	0,66	3,78	0,45	1,36	0,44	1,28	0,35	0,73	0,35	0,69	0,22	0,23	0,22	0,23
41	1,51	33,9	0,97	10,4	0,74	5,11	0,67	3,97	0,46	1,43	0,45	1,35	0,36	0,76	0,35	0,72	0,23	0,24	0,23	0,24
42	1,55	35,6	0,99	10,9	0,76	5,36	0,69	4,16	0,47	1,5	0,46	1,42	0,37	0,8	0,36	0,76	0,23	0,26	0,23	0,25
43	1,59	37,3	1,02	11,4	0,78	5,62	0,71	4,36	0,48	1,57	0,47	1,48	0,38	0,84	0,37	0,8	0,24	0,27	0,24	0,26
44	1,63	39,1	1,04	12	0,79	5,88	0,72	4,57	0,49	1,65	0,48	1,55	0,39	0,88	0,38	0,83	0,25	0,28	0,24	0,27
45	1,66	40,9	1,06	12,5	0,81	6,15	0,74	4,78	0,5	1,72	0,49	1,62	0,4	0,92	0,39	0,87	0,25	0,29	0,25	0,29
46	1,7	42,7	1,09	13,1	0,83	6,43	0,76	4,99	0,51	1,8	0,5	1,7	0,4	0,96	0,4	0,91	0,26	0,3	0,25	0,3
47	1,74	44,6	1,11	13,7	0,85	6,71	0,77	5,21	0,52	1,88	0,51	1,77	0,41	1	0,41	0,95	0,26	0,32	0,26	0,31
48	1,77	46,5	1,13	14,3	0,87	7	0,79	5,44	0,54	1,96	0,52	1,85	0,42	1,05	0,41	0,99	0,27	0,33	0,26	0,32
49	1,81	48,5	1,16	14,9	0,89	7,3	0,8	5,67	0,55	2,04	0,53	1,93	0,43	1,09	0,42	1,04	0,27	0,34	0,27	0,34
50	1,85	50,5	1,18	15,5	0,9	7,6	0,82	5,90	0,56	2,13	0,55	2,01	0,44	1,13	0,43	1,08	0,28	0,35	0,28	0,35
52	1,92	54,6	1,23	16,7	0,94	8,22	0,85	6,38	0,58	2,3	0,57	2,17	0,46	1,23	0,45	1,17	0,29	0,38	0,29	0,38
54	1,99	58,9	1,28	18,1	0,98	8,86	0,89	6,88	0,6	2,48	0,59	2,34	0,47	1,32	0,47	1,26	0,3	0,41	0,3	0,41
56	2,07	63,3	1,32	19,4	1,01	9,53	0,92	7,40	0,62	2,67	0,61	2,52	0,49	1,42	0,48	1,35	0,31	0,44	0,31	0,44
58	2,14	67,9	1,37	20,8	1,05	10,2	0,95	7,94	0,65	2,86	0,63	2,7	0,51	1,53	0,5	1,45	0,32	0,47	0,32	0,46
60	2,22	72,7	1,42	22,3	1,08	10,9	0,98	8,50	0,67	3,06	0,65	2,89	0,53	1,63	0,52	1,55	0,34	0,5	0,33	0,49
62	2,29	77,6	1,47	23,8	1,12	11,7	1,02	9,07	0,69	3,27	0,68	3,08	0,54	1,74	0,53	1,66	0,35	0,53	0,34	0,51
64	2,36	82,7	1,51	25,4	1,15	12,4	1,05	9,67	0,71	3,48	0,7	3,29	0,56	1,86	0,55	1,77	0,36	0,56	0,35	0,54
66	2,44	87,9	1,56	27	1,19	13,2	1,08	10,3	0,74	3,7	0,72	3,5	0,58	1,98	0,57	1,88	0,37	0,6	0,36	0,58
68	2,51	93,4	1,61	28,6	1,23	14,1	1,12	10,9	0,76	3,93	0,74	3,71	0,6	2,1	0,59	1,99	0,38	0,64	0,37	0,61
70	2,59	98,9	1,65	30,3	1,26	14,9	1,15	11,6	0,78	4,17	0,76	3,93	0,61	2,22	0,6	2,11	0,39	0,68	0,39	0,65
72	2,66	104,7	1,7	32,1	1,3	15,8	1,18	12,2	0,8	4,41	0,79	4,16	0,63	2,35	0,62	2,23	0,4	0,71	0,4	0,69
74			1,75	33,9	1,34	16,6	1,21	12,9	0,83	4,66	0,81	4,39	0,65	2,48	0,64	2,36	0,41	0,76	0,41	0,72
76			1,8	35,8	1,37	17,6	1,25	13,6	0,85	4,91	0,83	4,63	0,67	2,62	0,66	2,49	0,43	0,8	0,42	0,76
78			1,84	37,7	1,41	18,5	1,28	14,4	0,85	5,17	0,85	4,88	0,69	2,76	0,67	2,62	0,44	0,84	0,43	0,81
80			1,89	39,6	1,45	19,4	1,31	15,1	0,89	5,44	0,87	5,14	0,7	2,9	0,69	2,76	0,45	0,88	0,44	0,85
85			2,01	44,7	1,54	22	1,4	17,1	0,95	6,14	0,93	5,8	0,75	3,28	0,73	3,11	0,48	1	0,47	0,96
90			2,13	50,1	1,63	24,6	1,48	19,1	1	6,89	0,98	6,5	0,79	3,68	0,78	3,49	0,5	1,12	0,5	1,07
95			2,25	55,9	1,72	27,4	1,56	21,3	1,06	7,67	1,04	7,24	0,83	4,1	0,82	3,89	0,53	1,24	0,52	1,19

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ (1) в мм	133×4		152×4.5		159×4.5		194×6		194×5		219×7		219×6	
(2) G в т/ч	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м
100	2,36	61,9	1,81	30,4	1,64	23,6	1,12	8,5	1,09	8,02	0,88	4,54	0,86	4,31
105	2,48	68,3	1,9	33,5	1,72	26	1,17	9,37	1,15	8,85	0,92	5	0,91	4,75
110	2,6	74,9	1,99	36,8	1,81	28,6	1,23	10,3	1,2	9,71	0,97	5,49	0,95	5,22
115	2,72	81,9	2,08	40,2	1,89	31,2	1,28	11,2	1,25	10,6	1,01	6	0,99	5,7
120	2,84	89,1	2,17	43,8	1,97	34	1,34	12,2	1,31	11,9	1,05	6,53	1,03	6,21
125	2,95	96,7	2,26	47,5	2,05	36,9	1,39	13,3	1,36	12,5	1,1	7,09	1,08	6,74
130	3,07	104,6	2,35	51,4	2,13	39,9	1,45	14,4	1,42	13,6	1,14	7,67	1,12	7,29
135			2,44	55,4	2,22	43	1,51	15,5	1,47	14,6	1,19	8,27	1,16	7 86
140			2,53	59,6	2,3	46,3	1,56	16,7	1,53	15,7	1,23	8,89	1,21	8,45
145			2,62	63,9	2,38	49,6	1,62	17,9	1,58	16,9	1,27	9,54	1,25	9,06
150			2,71	68,4	2,46	53,1	1,67	19,1	1,64	18,1	1,32	10,2	1,29	9,7
155			2,8	73	2,54	56,7	1,73	20,4	1,69	19,3	1,36	10,9	1,34	10,4
160			2,89	77,8	2,63	60,4	1,78	21,8	1,75	20,5	1,41	11,6	1,38	11
165			2,98	82,7	2,71	64,3	1,84	23,1	1,8	21,8	1,45	12,3	1,42	11,7
170			3,07	87,8	2,79	68,2	1,9	24,6	1,85	23,2	1,49	13,1	1,47	12,5
175			3,16	93,1	2,87	72,3	1,95	26	1,91	24,6	1,54	13,9	1,51	13,2
180							2,01	27,5	1,96	26	1,58	14,7	1,55	14
190							2,12	30,7	2,07	29	1,67	16,4	1,64	15,6
200							2,23	34	2,18	32,1	1,76	18,2	1,72	17,2
210							2,34	37,5	2,29	35,4	1,85	20	1,81	19
220							2,45	41,1	2,4	34,8	1,93	22	1,9	20,9
230							2,56	45	2,51	42,4	2,02	24	1,98	22,8
240							2,68	49	2,62	46,2	2,11	26,1	2,07	24,8
250							2,79	53,1	2,73	50,2	2,2	28,4	2,16	26,9
260							2,9	57,5	2,84	54,2	2,29	30,7	2,24	29,1
270							3,01	62	2,95	58,5	2,37	33,1	2,33	31,4
280							3,12	66,6	3,05	62,9	2,46	35,6	2,41	33,8
290							3,23	71,5	3,16	67,5	2,55	38,2	2,5	36,3
300							3,35	76,5	3,27	72,2	2,64	40,8	2,59	38,8
310							3,46	81,7	3,38	77,1	2,72	43,6	2,67	41,4

$D_н \times s$ (1) в мм	273×8		273×7		325×8		377×9		426×10		426×7		426×6	
(2) G в т/ч	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $w_в$ м/сек	(4) $\Delta h_в$ кгс/м² м
100	0,56	1,38	0,55	1,32	0,39	0,52	0,29	0,25	0,22	0,13	0,22	0,12	0,22	0,12
105	0,59	1,52	0,58	1,46	0,41	0,58	0,3	0,27	0,24	0,14	0,23	0,13	0,23	0,13
110	0,62	1,67	0,61	1,6	0,43	0,63	0,32	0,3	0,25	0,16	0,24	0,14	0,24	0,14
115	0,64	1,82	0,63	1,75	0,44	0,69	0,33	0,32	0,26	0,17	0,25	0,16	0,25	0,15
120	0,67	1,99	0,66	1,91	0,46	0,75	0,34	0,34	0,27	0,19	0,26	0,17	0,26	0,17
125	0,7	2,15	0,68	2,07	0,48	0,82	0,36	0,37	0,28	0,2	0,27	0,19	0,27	0,18
130	0,73	2,33	0,72	2,24	0,5	0,88	0,37	0,4	0,29	0,22	0,28	0,2	0,28	0,2
135	0,75	2,51	0,74	2,41	0,52	0,95	0,39	0,43	0,3	0,23	0,29	0,22	0,29	0,21
140	0,78	2,7	0,77	2,59	0,54	1,03	0,4	0,47	0,31	0,25	0,3	0,23	0,3	0,23
145	0,81	2,9	0,8	2,78	0,56	1,1	0,42	0,5	0,32	0,27	0,32	0,25	0,31	0,24
150	0,84	3,1	0,83	2,98	0,58	1,18	0,43	0,53	0,34	0,28	0,33	0,27	0,32	0,26
155	0,87	3,31	0,85	3,18	0,6	1,26	0,44	0,57	0,35	0,3	0,34	0,28	0,33	0,27
160	0,89	3,53	0,88	3,39	0,62	1,34	0,46	0,61	0,36	0,32	0,35	0,3	0,34	0,29
165	0,92	3,75	0,91	3,6	0,64	1,42	0,47	0,65	0,37	0,34	0,36	0,31	0,36	0,31
170	0,95	3,99	0,94	3,83	0,66	1,51	0,49	0,69	0,38	0,36	0,37	0,33	0,37	0,33
175	0,98	4,22	0,96	4,05	0,68	1,6	0,5	0,73	0,39	0,38	0,38	0,35	0,38	0,34
180	1,01	4,47	0,99	4,29	0,7	1,69	0,52	0,77	0,4	0,4	0,39	0,37	0,39	0,36
190	1,06	4,98	1,05	4,78	0,74	1,89	0,54	0,86	0,43	0,45	0,41	0,42	0,41	0,41
200	1,12	5,52	1,1	5,3	0,77	2,09	0,57	0,95	0,45	0,5	0,44	0,46	0,43	0,45
210	1,17	6,08	1,16	5,84	0,81	2,31	0,6	1,05	0,47	0,55	0,46	0,51	0,45	0,5
220	1,23	6,67	1,21	6,41	0,85	2,53	0,63	1,15	0,49	0,6	0,48	0,56	0,47	0,54
230	1,29	7,29	1,27	7	0,89	2,77	0,66	1,26	0,51	0,66	0,5	0,61	0,5	0,59
240	1,34	7,94	1,32	7,63	0,93	3,01	0,69	1,37	0,54	0,72	0,52	0,66	0,52	0,65
250	1,4	8,62	1,38	8,27	0,97	3,27	0,72	1,49	0,56	0,78	0,54	0,72	0,54	0,7
260	1,45	9,32	1,43	8,95	1,01	3,54	0,75	1,61	0,58	0,84	0,57	0,78	0,56	0,76
270	1,51	10,1	1,49	9,65	1,04	3,81	0,77	1,73	0,61	0,91	0,59	0,84	0,58	0,82
280	1,57	10,8	1,54	10,4	1,08	4,1	0,8	1,86	0,63	0,98	0,61	0,9	0,6	0,88
290	1,62	11,6	1,6	11,1	1,12	4,4	0,83	2	0,65	1,05	0,63	0,97	0,62	0,95
300	2,08	12,4	1,65	11,9	1,16	4,71	0,86	2,14	0,67	1,12	0,65	1,04	0,65	1,01
310	1,73	13,3	1,71	12,7	1,2	5,03	0,89	2,28	0,69	1,2	0,67	1,11	0,67	1,08

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ (1) в мм	219×7		219×6		273×8		273×7		325×8		377×9		426×10	
(2) G в т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
320	2,81	46,5	2,76	44,1	1,79	14,1	1,76	13,6	1,24	5,36	0,92	2,43	0,72	1,28
330	2,9	49,4	2,84	46,9	1,85	15	1,82	14,4	1,28	5,7	0,95	2,59	0,74	1,36
340	2,99	52,5	2,93	49,8	1,9	15,9	1,87	15,3	1,32	6,05	0,97	2,75	0,76	1,44
350	3,08	55,6	3,02	52,8	1,96	16,9	1,93	16,2	1,35	6,41	1	2,91	0,78	1,53
360	3,16	58,8	3,1	55,9	2,01	17,9	1,98	17,2	1,39	6,78	1,03	3,08	0,81	1,61
370	3,25	62,1	3,19	59	2,07	18,9	2,04	18,1	1,43	7,16	1,06	3,25	0,83	1,71
380	3,34	65,5	3,28	62,3	2,13	19,9	2,09	19,1	1,47	7,55	1,09	3,43	0,85	1,8
390	3,43	69	3,36	65,6	2,18	21	2,15	20,1	1,51	7,95	1,12	3,62	0,87	1,9
400	3,52	72,6	3,45	69	2,24	22	2,2	21,2	1,55	8,37	1,15	3,8	0,9	1,99
410	3,6	76,3	3,53	72,5	2,29	23,2	2,26	22,2	1,59	8,79	1,18	4	0,92	2,09
420	3,69	80	3,62	76	2,35	24,3	2,31	23,4	1,62	9,23	1,2	4,19	0,94	2,2
430	3,78	83,9	3,71	79,7	2,4	25,5	2,37	24,5	1,66	9,67	1,23	4,4	0,96	2,3
440	3,87	87,8	3,79	83,5	2,46	26,7	2,42	25,6	1,7	10,1	1,26	4,6	0,99	2,41
450	3,96	91,9	3,88	87,3	2,52	27,9	2,48	26,8	1,74	10,6	1,29	4,81	1,01	2,52
460	4,04	96	3,97	91,2	2,57	29,2	2,53	28	1,78	11,1	1,32	5,03	1,03	2,64
470	4,13	100,2	4,05	95,2	2,63	30,5	2,59	29,2	1,82	11,6	1,35	5,25	1,05	2,75
480			4,14	99,3	2,68	31,8	2,64	30,5	1,86	12	1,38	5,48	1,08	2,87
490			4,22	103,5	2,74	33,1	2,7	31,8	1,9	12,6	1,4	5,71	1,1	2,99
500					2,8	35,5	2,75	34	1,93	13,1	1,43	5,94	1,12	3,12
520					2,91	38,3	2,86	36,8	2,01	14,1	1,49	6,43	1,16	3,37
540					3,02	41,3	2,97	39,6	2,09	15,3	1,55	6,93	1,21	3,63
560					3,13	44,3	3,08	42,6	2,17	16,4	1,6	7,46	1,25	3,91
580					3,24	47,5	3,19	45,6	2,24	17,6	1,66	8	1,3	4,19
600					3,36	49,6	3,3	48,8	2,32	18,8	1,72	8,56	1,34	4,49
620					3,47	53	3,41	50,9	2,4	20,1	1,78	9,14	1,39	4,79
640					3,58	56,5	3,52	54,2	2,48	21,4	1,83	9,74	1,43	5,1
660					3,69	60,1	3,63	57,7	2,55	22,8	1,89	10,4	1,48	5,43
680					3,8	63,8	3,74	61,2	2,63	24,2	1,95	11	1,52	5,76
700					3,91	67,6	3,85	64,9	2,71	25,6	2,01	11,7	1,57	6,11
720					4,03	71,5	3,96	68,6	2,79	27,1	2,06	12,3	1,61	6,46

$D_н \times s$ (1) в мм	426×7		426×6		478×7		478×6		529×7		529×6		630×8		630×7	
(2) G т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
320	0,7	1,18	0,69	1,15	0,55	0,63	0,54	0,62	0,45	0,37	0,44	0,36				
330	0,72	1,26	0,71	1,22	0,57	0,67	0,56	0,66	0,46	0,39	0,46	0,38				
340	0,74	1,33	0,73	1,3	0,58	0,71	0,58	0,7	0,47	0,41	0,47	0,41				
350	0,76	1,41	0,75	1,38	0,6	0,76	0,6	0,74	0,49	0,44	0,48	0,43				
360	0,78	1,5	0,78	1,46	0,62	0,8	0,61	0,78	0,5	0,46	0,5	0,45				
370	0,81	1,58	0,8	1,54	0,63	0,85	0,63	0,83	0,52	0,49	0,51	0,48				
380	0,83	1,67	0,82	1,62	0,65	0,89	0,65	0,87	0,53	0,52	0,53	0,51				
390	0,85	1,75	0,84	1,71	0,67	0,94	0,66	0,92	0,54	0,54	0,54	0,54				
400	0,87	1,85	0,86	1,8	0,69	0,99	0,68	0,97	0,56	0,57	0,55	0,56				
410	0,89	1,94	0,88	1,89	0,7	1,04	0,7	1,02	0,57	0,6	0,57	0,59				
420	0,91	2,04	0,91	1,98	0,72	1,09	0,71	1,07	0,58	0,63	0,58	0,62				
430	0,94	2,13	0,93	2,08	0,74	1,14	0,73	1,12	0,6	0,66	0,59	0,65				
440	0,96	2,23	0,95	2,18	0,75	1,2	0,75	1,17	0,61	0,69	0,61	0,68				
450	0,98	2,34	0,97	2,28	0,77	1,25	0,77	1,22	0,63	0,72	0,62	0,71				
460	1	2,44	0,99	2,38	0,79	1,31	0,78	1,28	0,64	0,76	0,64	0,74				
470	1,02	2,55	1,01	2,48	0,81	1,37	0,8	1,34	0,65	0,79	0,65	0,77				
480	1,04	2,66	1,03	2,59	0,82	1,42	0,82	1,39	0,67	0,82	0,66	0,81				
490	1,07	2,77	1,06	2,7	0,84	1,48	0,83	1,45	0,68	0,86	0,68	0,84				
500	1,09	2,88	1,08	2,81	0,86	1,55	0,85	1,51	0,7	0,89	0,69	0,88	0,49	0,36	0,49	0,35
520	1,13	3,12	1,12	3,04	0,89	1,67	0,88	1,63	0,72	0,97	0,72	0,95	0,51	0,39	0,51	0,38
540	1,18	3,36	1,16	3,28	0,93	1,8	0,92	1,76	0,75	1,04	0,75	1,02	0,53	0,42	0,53	0,41
560	1,22	3,62	1,21	3,53	0,96	1,94	0,95	1,9	0,78	1,12	0,77	1,1	0,55	0,45	0,55	0,44
580	1,26	3,88	1,25	3,78	1	2,08	0,99	2,03	0,81	1,2	0,8	1,18	0,57	0,48	0,56	0,47
600	1,31	4,15	1,29	4,05	1,03	2,23	1,02	2,18	0,84	1,29	0,83	1,26	0,59	0,51	0,58	0,5
620	1,35	4,43	1,34	4,32	1,06	2,38	1,05	2,32	0,86	1,38	0,86	1,35	0,61	0,55	0,6	0,54
640	1,39	4,73	1,38	4,61	1,1	2,53	1,09	2,48	0,89	1,47	0,88	1,44	0,63	0,58	0,62	0,57
660	1,44	5,03	1,42	4,9	1,13	2,69	1,12	2,63	0,92	1,56	0,91	1,53	0,65	0,62	0,64	0,61
680	1,48	5,33	1,47	5,7	1,17	2,86	1,16	2,8	0,95	1,65	0,94	1,62	0,67	0,66	0,66	0,65
700	1,52	5,65	1,51	5,51	1,2	3,03	1,19	2,96	0,97	1,75	0,97	1,72	0,69	0,7	0,68	0,69
720	1,57	5,98	1,55	5,83	1,24	3,21	1,22	3,13	1	1,86	0,99	1,82	0,71	0,74	0,7	0,73

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ (1) в мм	273×8		273×7		325×8		377×9		426×10		426×7		426×6		478×7		478×6	
(2) G в т/ч	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м
740	4,14	75,5	4,07	72,5	2,86	28,6	2,12	13	1,66	6,82	1,61	6,32	1,59	6,16	1,27	3,39	1,25	3,31
760	4,25	79,6	4,18	76,5	2,94	30,2	2,18	13,7	1,7	7,2	1,65	6,66	1,64	6,5	1,3	3,57	1,29	3,49
780	4,36	83,9	4,29	80,5	3,02	31,8	2,24	14,5	1,75	7,58	1,7	7,02	1,68	6,84	1,34	3,76	1,33	3,68
800	4,47	88,3	4,41	84,7	3,09	33,5	2,29	15,2	1,79	7,97	1,74	7,38	1,72	7,2	1,37	3,95	1,36	3,87
820					3,17	35,2	2,35	16	1,84	8,38	1,78	7,76	1,77	7,56	1,41	4,16	1,39	4,06
840					3,25	36,9	2,41	16,8	1,88	8,79	1,83	8,14	1,81	7,94	1,44	4,36	1,43	4,27
860					3,33	38,7	2,46	17,6	1,93	9,22	1,87	8,53	1,85	8,32	1,48	4,57	1,46	4,47
880					3,4	40,5	2,52	18,4	1,97	9,65	1,91	8,93	1,9	8,71	1,51	4,79	1,5	4,68
900					3,48	42,4	2,58	19,3	2,02	10,1	1,95	9,34	1,94	9,11	1,54	5,01	1,53	4,9
920					3,56	44,3	2,64	20,1	2,06	10,5	2	9,76	1,98	9,52	1,58	5,23	1,56	5,12
940					3,64	46,2	2,69	21	2,11	11	2,05	10,2	2,03	9,94	1,61	5,46	1,6	5,34
960					3,71	48,2	2,75	21,9	2,15	11,5	2,09	10,6	2,07	10,4	1,65	5,7	1,63	5,57
980					3,79	50,2	2,81	22,8	2,2	12	2,13	11,1	2,11	10,8	1,68	5,94	1,67	5,81
1000					3,87	52,3	2,87	23,8	2,24	12,5	2,18	11,5	2,16	11,2	1,72	6,18	1,7	6,05
1020					3,95	54,4	2,92	24,7	2,29	13	2,22	12	2,2	11,7	1,75	6,43	1,73	6,29
1040					4,02	56,6	2,98	25,7	2,33	13,5	2,26	12,5	2,24	12,2	1,78	6,69	1,77	6,54
1060					4,1	58,8	3,04	26,7	2,38	14	2,31	13	2,28	12,6	1,82	6,95	1,8	6,79
1080					4,18	61	3,1	27,7	2,42	14,5	2,35	13,5	2,33	13,1	1,85	7,21	1,84	7,05
1100					4,25	63,3	3,15	28,8	2,46	15,1	2,39	14	2,37	13,6	1,89	7,48	1,87	7,31
1150					4,45	69,2	3,3	31,4	2,58	15,5	2,5	15,3	2,48	14,9	1,97	8,18	1,96	7,99
1200					4,64	75,3	3,44	34,2	2,69	17,9	2,61	15,6	2,59	16,2	2,06	8,9	2,04	8,71
1250					4,84	81,7	3,58	37,1	2,8	19,5	2,72	18	2,69	17,6	2,14	9,66	2,13	9,45
1300					5,03	88,4	3,73	40,2	2,91	21,1	2,83	19,5	2,8	19	2,23	10,4	2,21	10,2
1350					5,22	95,3	3,87	43,3	3,03	22,7	2,94	21	2,91	20,5	2,32	11,3	2,3	11
1400					5,42	102,5	4,01	46,6	3,14	24,4	3,05	22,6	3,02	22	2,4	12,1	2,38	11,8
1450							4,16	50	3,25	26,2	3,16	24,3	3,12	23,6	2,49	13	2,47	12,7
1500							4,3	53,5	3,36	28	3,26	26	3,23	25,3	2,57	13,9	2,55	13,6
1550							**4,44**	**57,1**	**3,47**	**29,9**	**3,37**	**27,7**	**3,34**	**27**	**2,66**	**14,9**	**2,64**	**14,5**
1600							**4,59**	**60,9**	**3,59**	**31,9**	**3,48**	**29,5**	**3,45**	**28,8**	**2,74**	**15,8**	**2,72**	**15,5**
1650							**4,73**	**64,7**	**3,7**	**35,9**	**3,59**	**31,4**	**3,56**	**33,6**	**2,83**	**16,8**	**2,81**	**16,5**

$D_н \times s$ (1) в мм	529×7		529×6		630×8		630×7		720×9		720×8		720×7		820×9		820×8	
(2) G в т/ч	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м	(3) v в м/сек	(4) Δh в кгс/м²м
740	1,03	1,96	1,02	1,92	0,73	0,78	0,72	0,77	0,55	0,39	0,55	0,38	0,55	0,38	0,42	0,19	0,42	0,19
760	1,06	2,07	1,05	2,03	0,74	0,82	0,74	0,81	0,57	0,41	0,57	0,4	0,56	0,4	0,44	0,2	0,43	0,2
780	1,09	2,18	1,08	2,13	0,76	0,87	0,76	0,85	0,58	0,43	0,58	0,42	0,58	0,42	0,45	0,21	0,45	0,21
800	1,11	2,29	1,11	2,24	0,78	0,91	0,78	0,9	0,6	0,45	0,6	0,45	0,59	0,44	0,46	0,23	0,46	0,22
820	1,14	2,41	1,13	2,36	0,8	0,96	0,8	0,94	0,61	0,47	0,61	0,47	0,61	0,46	0,47	0,24	0,47	0,23
840	1,17	2,53	1,16	2,47	0,82	1	0,82	0,99	0,63	0,5	0,63	0,49	0,62	0,48	0,48	0,25	0,48	0,25
860	1,2	2,65	1,19	2,59	0,84	1,05	0,84	1,04	0,64	0,52	0,64	0,51	0,64	0,51	0,49	0,26	0,49	0,26
880	1,23	2,77	1,22	2,72	0,86	1,1	0,86	1,08	0,66	0,55	0,66	0,54	0,65	0,53	0,51	0,27	0,5	0,27
900	1,25	2,9	1,24	2,84	0,88	1,15	0,88	1,13	0,67	0,57	0,67	0,56	0,67	0,56	0,52	0,29	0,51	0,28
920	1,28	3,03	1,27	2,97	0,9	1,21	0,9	1,19	0,69	0,6	0,69	0,59	0,68	0,58	0,53	0,3	0,53	0,29
940	1,31	3,16	1,3	3,1	0,92	1,26	0,92	1,24	0,7	0,62	0,7	0,61	0,7	0,61	0,54	0,31	0,54	0,31
960	1,34	3,3	1,33	3,23	0,94	1,31	0,93	1,29	0,72	0,65	0,72	0,64	0,71	0,63	0,55	0,32	0,55	0,32
980	1,36	3,44	1,35	3,37	0,96	1,37	0,95	1,34	0,73	0,68	0,73	0,67	0,73	0,66	0,56	0,34	0,56	0,33
1000	1,39	3,58	1,38	3,51	0,98	1,42	0,97	1,4	0,75	0,71	0,75	0,7	0,74	0,69	0,57	0,35	0,57	0,35
1020	1,42	3,72	1,41	3,65	1	1,48	0,99	1,46	0,76	0,73	0,76	0,72	0,76	0,71	0,59	0,37	0,58	0,36
1040	1,45	3,87	1,44	3,79	1,02	1,54	1,01	1,51	0,78	0,76	0,78	0,75	0,77	0,74	0,6	0,38	0,59	0,38
1060	1,48	4,02	1,47	3,94	1,04	1,6	1,03	1,57	0,79	0,79	0,79	0,78	0,79	0,77	0,61	0,4	0,61	0,39
1080	1,5	4,17	1,49	4,09	1,06	1,66	1,05	1,63	0,81	0,82	0,8	0,81	0,8	0,8	0,62	0,41	0,62	0,41
1100	1,53	4,33	1,52	4,24	1,08	1,72	1,07	1,69	0,82	0,85	0,82	0,84	0,82	0,83	0,63	0,43	0,63	0,42
1150	1,6	4,73	1,59	4,64	1,13	1,88	1,12	1,85	0,86	0,93	0,86	0,92	0,85	0,91	0,66	0,47	0,66	0,46
1200	1,67	5,15	1,66	5,05	1,18	2,05	1,17	2,02	0,9	1,02	0,89	1	0,89	0,99	0,69	0,51	0,69	0,5
1250	1,74	5,55	1,73	5,48	1,22	2,25	1,22	2,19	0,94	1,1	0,93	1,09	0,93	1,07	0,72	0,55	0,71	0,54
1300	1,81	6,05	1,8	5,93	1,27	2,41	1,27	2,37	0,97	1,19	0,97	1,18	0,96	1,16	0,75	0,59	0,74	0,59
1350	1,88	6,52	1,87	6,39	1,32	2,6	1,31	2,55	1,01	1,29	1,01	1,27	1	1,25	0,78	0,64	0,77	0,63
1400	**1,95**	**7,01**	**1,93**	**6,87**	**1,37**	**2,79**	**1,36**	**2,74**	**1,05**	**1,38**	**1,04**	**1,36**	**1,04**	**1,34**	**0,8**	**0,69**	**0,8**	**0,68**
1480	**2,02**	**7,52**	**2**	**7,37**	**1,42**	**2,99**	**1,41**	**2,94**	**1,09**	**1,49**	**1,08**	**1,46**	**1,07**	**1,44**	**0,83**	**0,74**	**0,83**	**0,73**
1500	**2,09**	**8,05**	**2,07**	**7,89**	**1,47**	**3,2**	**1,46**	**3,15**	**1,12**	**1,59**	**1,12**	**1,57**	**1,11**	**1,54**	**0,86**	**0,79**	**0,86**	**0,78**
1550	**2,16**	**8,6**	**2,14**	**8,42**	**1,52**	**3,42**	**1,51**	**3,36**	**1,16**	**1,7**	**1,16**	**1,67**	**1,15**	**1,65**	**0,89**	**0,85**	**0,89**	**0,83**
1600	**2,23**	**9,16**	**2,21**	**8,98**	**1,57**	**3,65**	**1,56**	**3,58**	**1,2**	**1,81**	**1,19**	**1,73**	**1,19**	**1,76**	**0,92**	**0,9**	**0,91**	**0,89**
1650	**2,3**	**9,74**	**2,28**	**9,55**	**1,62**	**3,88**	**1,61**	**3,81**	**1,24**	**1,92**	**1,23**	**1,89**	**1,22**	**1,87**	**0,95**	**0,96**	**0,94**	**0,95**

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

(1) $D_н \times s$ в мм / (2) G в т/ч	377×9		426×10		426×7		426×6		478×7		478×6		529×7		529×6		630×8		630×7	
	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м
1700	4,87	68,7	3,81	36	3,7	33,3	3,66	32,5	2,92	17,9	2,89	17,5	2,37	10,3	2,35	10,1	1,67	4,12	1,65	4,05
1750	5,02	72,8	3,92	38,2	3,81	35,3	3,77	34,4	3	18,9	2,98	18,5	2,44	11	2,42	10,7	1,71	4,36	1,7	4,29
1800	5,16	77	4,03	40,4	3,92	37,4	3,88	36,4	3,09	20	3,06	19,6	2,51	11,6	2,49	11,4	1,76	4,61	1,75	4,54
1850	5,3	81,4	4,15	42,6	4,03	39,5	3,99	38,5	3,17	21,2	3,15	20,7	2,58	12,2	2,56	12	1,81	4,87	1,8	4,79
1900	5,45	85,8	4,26	45	4,13	41,6	4,09	40,6	3,26	22,3	3,23	21,8	2,65	12,9	2,63	12,7	1,86	5,14	1,85	5,05
1950	5,59	90,4	4,37	47,4	4,24	43,9	4,2	42,8	3,35	23,5	3,32	23	2,72	13,6	2,69	13,3	1,91	5,42	1,9	5,32
2000			4,48	49,8	4,35	46,1	4,31	45	3,43	24,7	3,4	24,2	2,79	14,3	2,76	14	1,96	5,7	1,95	5,6
2100			4,71	55	4,57	50,9	4,53	49,6	3,6	27,3	3,57	26,7	2,92	15,8	2,9	15,5	2,06	6,28	2,04	6,18
2200			4,93	60,3	4,79	55,8	4,74	54,4	3,77	29,9	3,74	29,3	3,06	17,3	3,04	17	2,16	6,89	2,14	6,78
2300			5,15	65,9	5	61	4,96	59,5	3,95	32,7	3,91	32	3,2	18,9	3,18	18,6	2,25	7,53	2,24	7,41
2400			5,38	71,8	5,22	66,5	5,17	64,8	4,12	35,6	4,08	34,8	3,34	20,6	3,32	20,2	2,35	8,2	2,34	8,07
2500			5,6	77,9	5,44	72,1	5,39	70,3	4,29	38,6	4,25	37,8	3,48	22,4	3,45	21,9	2,45	8,9	2,43	8,75
2600			5,83	84,2	5,66	78	5,6	76	4,46	41,8	4,42	40,9	3,62	24,2	3,59	23,7	2,55	9,63	2,53	9,47
2700			6,05	90,8	5,88	84,1	5,82	82	4,63	45,1	4,59	44,1	3,76	26,1	3,73	25,6	2,65	10,4	2,63	10,2
2800			6,27	97,7	6,09	90,4	6,03	88,2	4,8	48,5	4,76	47,4	3,9	28,1	3,87	27,5	2,74	11,2	2,73	11
2900			6,5	104,8	6,31	97	6,25	94,6	4,98	52	4,93	50,8	4,04	30,1	4,01	29,5	2,84	12	2,82	11,8
3000					6,53	103,8	6,47	101,2	5,15	55,6	5,1	54,4	4,18	32,2	4,15	31,6	2,94	12,8	2,92	12,6
3100									5,32	59,4	5,27	58,1	4,32	34,4	4,28	33,7	3,04	13,7	3,02	13,5
3200									5,49	63,3	5,44	61,9	4,46	36,6	4,42	35,9	3,14	14,6	3,11	14,3
3300									5,66	67,3	5,61	65,8	4,6	39	4,56	38,2	3,23	15,5	3,21	15,2
3400									5,83	71,5	5,78	69,9	4,74	41,4	4,7	40,5	3,33	16,4	3,31	16,2
3500									6	75,7	5,95	74,1	4,87	43,8	4,84	43	3,43	17,4	3,41	17,2
3600									6,18	80,1	6,12	78,3	5,01	46,4	4,97	45,4	3,53	18,5	3,5	18,1
3700									6,35	84,6	6,29	82,8	5,15	49	5,11	48	3,63	19,5	3,6	19,2
3800									6,52	89,3	6,46	87,3	5,29	51,7	5,25	50,6	3,72	20,6	3,7	20,2
3900									6,69	94	6,63	91,9	5,43	54,4	5,39	53,3	3,82	21,7	3,8	21,3
4000									6,86	98,9	6,8	96,7	5,57	57,3	5,53	56,1	3,92	22,8	3,89	22,4
4200									7,21	109,1	7,14	126,6	5,85	63,1	5,8	61,9	4,11	25,1	4,09	24,7
4400													6,13	69,3	6,08	67,9	4,31	27,6	4,28	27,1
4600													6,41	75,7	6,35	74,2	4,51	30,1	4,48	29,6

(1) $D_н \times s$ в мм / (2) G в т/ч	720×9		720×8		720×7		820×9		820×8		920×10		920×9
	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек
1700	1,27	2,04	1,27	2,01	1,26	1,98	0,98	1,02	0,97	1	0,78	0,56	0,77
1750	1,31	2,16	1,3	2,13	1,3	2,1	1	1,08	1	1,06	0,8	0,59	0,79
1800	1,35	2,29	1,34	2,25	1,33	2,22	1,03	1,14	1,03	1,13	0,82	0,62	0,82
1850	1,39	2,42	1,38	2,38	1,37	2,35	1,06	1,2	1,06	1,19	0,84	0,66	0,84
1900	1,42	2,55	1,42	2,51	1,41	2,48	1,09	1,27	1,09	1,25	0,87	0,7	0,86
1950	1,46	2,69	1,45	2,65	1,45	2,61	1,2	1,34	1,11	1,32	0,89	0,73	0,89
2000	1,5	2,83	1,49	2,78	1,48	2,74	1,15	1,41	1,14	1,39	0,91	0,77	0,91
2100	1,57	3,12	1,57	3,08	1,56	3,02	1,21	1,55	1,2	1,53	0,96	0,85	0,95
2200	1,65	3,42	1,64	3,37	1,63	3,32	1,26	1,7	1,26	1,68	1	0,93	1
2300	1,72	3,74	1,71	3,68	1,7	3,63	1,32	1,86	1,31	1,84	1,05	1,02	1,04
2400	1,8	4,07	1,79	4,01	1,78	3,95	1,38	2,03	1,37	2	1,09	1,11	1,09
2500	1,87	4,42	1,86	4,35	1,85	4,29	1,44	2 2	1,43	2,17	1,14	1,2	1,13
2600	1,95	4,78	1,94	4,7	1,93	4,64	1,49	2,38	1,49	2,35	1,19	1,3	1,18
2700	2,02	5,15	2,01	5,07	2	5	1,55	2,57	1,54	2,53	1,23	1,4	1,23
2800	2,1	5,54	2,09	5,46	2,07	5,38	1,61	2,76	1,6	2,72	1,28	1,51	1,27
2900	2,17	5,94	2,16	5,85	2,15	5,77	1,67	2,96	1,66	2,92	1,32	1,62	1,32
3000	2,25	6,36	2,24	6,26	2,22	6,17	1,72	3,17	1,71	3,13	1,37	1,73	1,36
3100	2,32	6,79	2,31	6,69	2,3	6,59	1,78	3,38	1,77	3,34	1,41	1,85	1,41
3200	2,4	7,23	2,38	7,13	2,37	7,02	1,84	3,6	1,83	3,56	1,46	1,97	1,45
3300	2,47	7,69	2,46	7,58	2,45	7,47	1,9	3,83	1,89	3,78	1,5	2,1	1,5
3400	2,55	8,17	2,53	8,05	2,52	7,93	1,95	4,07	1,94	4,02	1,55	2,23	1,54
3500	2,62	8,65	2,61	8,53	2,59	8,4	2,01	4,31	2	4,26	1,6	2,36	1,59
3600	2,7	9,16	2,68	9,02	2,67	8,89	2,07	4,56	2,06	4,5	1,64	2,5	1,63
3700	2,77	9,67	2,76	9,53	2,74	9,39	2,12	4,82	2,11	4,76	1,69	2,64	1,68
3800	2,85	10,2	2,83	10	2,82	9,9	2,18	5,08	2,17	5,02	1,73	2,78	1,73
3900	2,92	10,7	2,91	10,6	2,89	10,4	2,24	5,35	2,23	5,28	1,78	2,93	1,77
4000	3	11,3	2,98	11,1	2,96	11	2,3	5,63	2,29	5,56	1,82	3,08	1,82
4200	3,15	12,5	3,13	12,3	3,11	12,1	2,41	6,21	2,4	6,13	1,92	3,4	1,91
4400	3,3	13,7	3,28	13,5	3,26	13,3	2,53	6,81	2,51	6,73	2,01	3,73	2
4600	3,45	14,9	3,43	14,7	3,41	14,5	2,64	7,45	2,63	7,35	2,1	4,08	2,09

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times s$ (1) в мм	920×9		920×8		1020×11		1020×10		1020×8		1220×12		1220×9	
$G_в$ (2) т/ч	$\Delta h_в$ (4) кгс/м² м		(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м
1700	0,55		0,77	0,54	0,63	0,32	0,63	0,32	0,62	0,31	0,44	0,13	0,43	0,12
1750	0,58		0,79	0,58	0,65	0,34	0,65	0,34	0,64	0,33	0,45	0,13	0,45	0,13
1800	0,62		0,81	0,61	0,67	0,36	0,66	0,36	0,66	0,35	0,46	0,14	0,46	0,14
1850	0,65		0,84	0,64	0,69	0,38	0,68	0,38	0,68	0,37	0,48	0,15	0,47	0,15
1900	0,69		0,86	0,68	0,7	0,41	0,7	0,4	0,7	0,39	0,49	0,16	0,49	0,15
1950	0,72		0,88	0,72	0,72	0,43	0,72	0,42	0,71	0,41	0,5	0,17	0,5	0,16
2000	0,76		0,9	0,75	0,74	0,45	0,74	0,44	0,73	0,44	0,51	0,17	0,51	0,17
2100	0,84		0,95	0,83	0,78	0,49	0,78	0,49	0,77	0,48	0,54	0,19	0,54	0,19
2200	0,92		0,99	0,92	0,82	0,54	0,81	0,54	0,81	0,53	0,57	0,21	0,56	0,21
2300	1,01		1,04	1	0,85	0,59	0,85	0,59	0,84	0,58	0,59	0,23	0,59	0,22
2400	1,10		1,08	1,08	0,89	0,65	0,89	0,64	0,88	0,63	0,62	0,25	0,61	0,24
2500	1,19		1,13	1,17	0,93	0,7	0,92	0,69	0,92	0,68	0,65	0,27	0,64	0,27
2600	1,29		1,18	1,27	0,96	0,76	0,96	0,75	0,95	0,74	0,67	0,29	0,66	0,29
2700	1,39		1,22	1,37	1	0,82	1	0,81	0,99	0,79	0,7	0,32	0,69	0,31
2800	1,49		1,27	1,48	1,04	0,88	1,03	0,87	1,03	0,85	0,72	0,34	0,72	0,33
2900	1,6		1,31	1,58	1,08	0,94	1,07	0,93	1,06	0,91	0,75	0,37	0,74	0,36
3000	1,71		1,36	1,69	1,11	1,01	1,11	1	1,1	0,98	0,77	0,39	0,77	0,38
3100	1,83		1,4	1,81	1,15	1,08	1,15	1,07	1,14	1,05	0,8	0,42	0,79	0,41
3200	1,95		1,45	1,93	1,19	1,15	1,18	1,14	1,17	1,11	0,83	0,45	0,82	0,44
3300	2,07		1,49	2,05	1,22	1,22	1,22	1,21	1,21	1,18	0,85	0,47	0,84	0,46
3400	2,2		1,53	2,17	1,26	1,3	1,26	1,28	1,25	1,26	0,88	0,5	0,87	0,49
3500	2,33		1,58	2,3	1,3	1,37	1,29	1,36	1,28	1,33	0,9	0,53	0,89	0,52
3600	2,47		1,63	2,44	1,34	1,45	1,33	1,44	1,32	1,41	0,93	0,57	0,92	0,55
3700	2,61		1,67	2,58	1,37	1,54	1,37	1,52	1,36	1,49	0,96	0,6	0,95	0,58
3800	2,75		1,72	2,72	1,41	1,62	1,4	1,6	1,39	1,57	0,98	0,63	0,97	0,61
3900	2,9		1,76	2,86	1,45	1,71	1,44	1,69	1,43	1,65	1,01	0,66	1	0,65
4000	3,05		1,81	3,01	1,48	1,8	1,48	1,78	1,47	1,74	1,03	0,7	1,02	0,68
4200	3,36		1,9	3,32	1,56	1,98	1,55	1,96	1,54	1,92	1,08	0,77	1,07	0,75
4400	3,69		1,99	3,64	1,63	2,17	1,63	2,15	1,61	2,11	1,14	0,84	1,12	0,82
4600	4,03		2,08	3,98	1,71	2,37	1,69	2,35	1,69	2,3	1,19	0,92	1,17	0,9

$D_н \times s$ (1) в мм	630×8		630×7		720×9		720×8		720×7		820×9		820×8		920×10
$G_в$ (2) т/ч	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м² м	(3) $v_в$ м/сек
4800	4,7	32,8	4,67	32,3	3,6	16,3	3,58	16	3,56	15,8	2,76	8,11	2,74	8	2,19
5000	4,9	35,6	4,87	35	3,75	17,7	3,73	17,4	3,71	17,1	2,87	8,8	2,86	8,68	2,28
5200	5,09	38,5	5,06	37,9	3,9	19,1	3,88	18,8	3,85	18,5	2,99	9,52	2,97	9,39	2,37
5400	5,29	41,5	5,26	40,8	4,05	20,6	4,02	20,3	4	20	3,1	10,3	3,09	10,1	2,46
5600	5,49	44,7	5,45	43,9	4,2	22,2	4,17	21,8	4,15	21,5	3,22	11	3,2	10,9	2,55
5800	5,68	47,9	5,65	47,1	4,35	23,8	4,32	23,4	4,3	23,1	3,33	11,8	3,31	11,7	2,64
6000	5,88	51,3	5,84	50,4	4,50	25,4	4,47	25,1	4,45	24,7	3,45	12,7	3,43	12,5	2,74
6200	6,07	54,7	6,04	53,8	4,65	27,2	4,62	26,8	4,59	26,4	3,56	13,5	3,54	13,4	2,83
6400	6,27	58,3	6,23	57,4	4,8	28,9	4,77	28,5	4,74	28,1	3,68	14,4	3,66	14,2	2,92
6600	6,47	62	6,42	61	4,95	30,8	4,92	30,3	4,89	29,9	3,79	15,3	3,77	15,1	3,01
6800	6,66	65,9	6,62	64,7	5,1	32,7	5,07	32,2	5,04	31,7	3,9	16,3	3,88	16,1	3,1
7000	6,86	69,8	6,81	68,6	5,25	34,6	5,22	34,1	5,19	33,6	4,02	17,2	4	17	3,19
7200	7,05	73,8	7,01	72,6	5,4	36,6	5,37	36,1	5,34	35,5	4,13	18,2	4,11	18	3,28
7400	7,25	78	7,2	76,7	5,55	38,7	5,51	38,1	5,48	37,5	4,25	19,3	4,23	19	3,37
7600	7,45	82,3	7,4	80,9	5,7	40,8	5,66	40,2	5,63	39,6	4,36	20,3	4,34	20,1	3,47
7800	7,64	86,7	7,59	85,2	5,85	43	5,81	42,3	5,78	41,7	4,48	21,4	4,46	21,1	3,56
8000	7,84	91,2	7,79	89,6	6	45,2	5,96	44,5	5,93	43,9	4,59	22,5	4,57	22,2	3,65
8200	8,03	95,8	7,98	94,2	6,15	47,5	6,11	46,8	6,08	46,1	4,71	23,7	4,69	23,4	3,74
8400	8,23	100,5	8,18	98,8	6,3	49,8	6,26	49,1	6,22	48,4	4,82	24,8	4,8	24,5	3,83
8600			8,37	103,6	6,45	52,2	6,41	51,5	6,37	50,7	4,94	26	4,91	25,7	3,92
8800					6,6	54,7	6,56	53,9	6,52	53,1	5,05	27,3	5,03	26,9	4,01
9000					6,75	57,2	6,71	56,4	6,67	55,5	5,17	28,5	5,14	28,1	4,1
9200					6,9	59,8	6,86	58,9	6,82	58	5,28	29,8	5,26	29,4	4,2
9400					7,05	62,4	7,01	61,5	6,97	60,6	5,4	31,1	5,37	30,7	4,29
9600					7,2	65,1	7,15	64,1	7,11	63,2	5,51	32,4	5,49	32	4,38
9800					7,35	67,8	7,3	66,8	7,26	65,9	5,63	33,8	5,6	33,4	4,47
10000					7,5	70,6	7,45	69,6	7,41	68,6	5,74	35,2	5,71	34,7	4,56
10500											6,03	38,9	6	38,3	4,79
11000											6,32	42,6	6,25	41,5	5,02
11500											6,6	46,5	6,54	45,3	5,24

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

$D_н \times S$ (1) мм	920×10	920×9		920×8		1020×11		1020×10		1020×8		1220×12		1220×9	
G (2) т/ч	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м	(3) v м/сек	(4) Δh кгс/м² м
4800	4,44	2,18	4,39	2,17	4,34	1,78	2,59	1,77	2,56	1,76	2,51	1,24	1	1,23	0,98
5000	4,82	2,27	4,76	2,26	4,7	1,85	2,81	1,85	2,78	1,83	2,72	1,29	1,09	1,27	1,06
5200	5,21	2,36	5,15	2,35	5,09	1,93	3,03	1,92	3	1,91	2,94	1,34	1,18	1,33	1,14
5400	5,62	2,45	5,55	2,44	5,49	2	3,27	1,99	3,23	1,98	3,17	1,39	1,27	1,38	1,23
5600	6,04	2,54	5,97	2,53	5,9	2,08	3,52	2,07	3,48	2,05	3,41	1,45	1,37	1,43	1,33
5800	6,48	2,63	6,4	2,62	6,33	2,15	3,78	2,14	3,74	2,13	3,66	1,5	1,47	1,48	1,43
6000	6,93	2,72	6,85	2,71	6,78	2,23	4,04	2,22	4	2,2	3,92	1,55	1,57	1,53	1,53
6200	7,4	2,81	7,32	2,8	7,23	2,3	4,31	2,29	4,27	2,27	4,18	1,6	1,68	1,59	1,63
6400	7,89	2,91	7,8	2,89	7,71	2,37	4,6	2,36	4,55	2,35	4,46	1,65	1,79	1,64	1,74
6600	8,39	3	8,29	2,98	8,2	2,45	4,89	2,44	4,84	2,42	4,74	1,7	1,9	1,69	1,85
6800	8,91	3,09	8,8	3,07	8,7	2,52	5,19	2,51	5,14	2,49	5,03	1,76	2,02	1,74	1,96
7000	9,44	3,18	9,33	3,16	9,22	2,6	5,5	2,59	5,44	2,56	5,33	1,81	2,14	1,79	2,08
7200	9,98	3,27	9,87	3,25	9,76	2,67	5,82	2,66	5,76	2,64	5,64	1,86	2,26	1,84	2,2
7400	10,5	3,36	10,4	3,34	10,3	2,74	6,15	2,73	6,08	2,71	5,96	1,91	2,39	1,89	2,33
7600	11,1	3,45	11	3,44	10,9	2,82	6,48	2,81	6,41	2,78	6,28	1,96	2,52	1,94	2,49
7800	11,7	3,54	11,6	3,53	11,4	2,89	6,83	2,88	6,76	2,86	6,62	2,01	2,65	1,99	2,59
8000	12,3	3,63	12,2	3,62	12	2,97	7,18	2,95	7,11	2,93	6,96	2,07	2,79	2,05	2,72
8200	13	3,72	12,8	3,71	12,7	3,04	7,55	3,03	7,47	3	7,31	2,12	2,93	2,1	2,86
8400	13,6	3,81	13,4	3,8	13,3	3,12	7,92	3,1	7,84	3,08	7,68	2,17	3,08	2,15	3
8600	14,2	3,9	14,1	3,89	13,9	3,19	8,3	3,18	8,21	3,15	8,04	2,22	3,23	2,2	3,14
8800	14,9	4	14,7	3,98	14,6	3,26	8,69	3,25	8,6	3,22	8,42	2,27	3,38	2,25	3,29
9000	15,6	4,09	15,4	4,07	15,2	3,34	9,09	3,32	9	3,30	8,81	2,32	3,53	2,3	3,44
9200	16,3	4,18	16,1	4,16	15,9	3,41	9,5	3,4	9,4	3,37	9,21	2,38	3,69	2,35	3,6
9400	17	4,27	16,8	4,25	16,6	3,49	9,92	3,47	9,81	3,44	9,61	2,43	3,85	2,4	3,75
9600	17,8	4,36	17,5	4,34	17,3	3,56	10,3	3,55	10,2	3,52	10	2,48	4,02	2,45	3,92
9800	18,5	4,45	18,3	4,43	18,1	3,63	10,8	3,62	10,7	3,59	10,4	2,53	4,19	2,51	4,08
10000	19,3	4,54	19	4,52	18,8	3,71	11,2	3,69	11,1	3,66	10,9	2,58	4,36	2,56	4,25
10500	21,2	4,77	21	4,75	20,7	3,89	12,4	3,88	12,2	3,85	12	2,71	4,81	2,68	4,68
11000	23,3	4,99	23	4,97	22,8	4,08	13,6	4,06	13,4	4,03	13,2	2,84	5,28	2,81	4,14
11500	25,5	5,22	25,2	5,2	24,9	4,26	14,8	4,25	14,7	4,21	14,4	2,97	5,77	2,94	5,62

Note. Heavy line designated the boundary/interface between the transfer and quadratic region.

Key: (1) in mm; (2) in t/h; (3) m/s; (4) kg/m^2 m.

Pages 126-129.

Table 9.12. Equivalent lengths of local resistance with $k_э$=0.2 мм for tubes D_y=25÷400 мм.

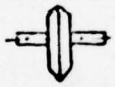
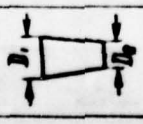
(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений							
		32	33.5	38	42.3	44.5	45	48	57
(4) Задвижка		–	–	–	–	–	–	–	0.65
(5) Вентиль:									
(6) с вертикальным шпинделем		5.1	5.4	6	6.9	7.7	7.8	8.1	8.4
(7). косым		0.57	0.54	0.64	0.69	0.72	0.73	0.76	0.92
(8) Обратный клапан:									
(8а) поворотный („заслонка")		0.74	0.78	0.98	1.12	1.28	1.26	1.35	1.7
(8б) подъемный		4	4.2	5.25	6	6.7	6.8	7.3	9.10
(9) Сальниковый компенсатор:									
(9а) односторонний		–	–	–	–	–	–	–	–
(10) двусторонний		–	–	–	–	–	–	–	–
(11) Грязевик промывочный		–	–	–	–	–	–	–	–
(12) Отводы сварные одношовные с углом 30°	30°	–	–	–	–	–	–	–	–
45°	45°	–	–	–	–	–	–	–	–
60°	60°	–	–	–	–	–	–	–	–
90°		–	–	–	–	–	–	–	–
(13) Отводы сварные под углом 90°:									
(14) двухшовные R=1 D	R	–	–	–	–	–	–	–	–
(15) трехшовные R=1,5 D	R	–	–	–	–	–	–	–	–

Continuation Table 9.12.

$l_э$ при наружных диаметрах труб в мм

60	75.5	76	88.5	89	101.3	108	114	133	140	152	159	165	194	219	273	325	377	426
0,72	1	1	1,25	1,28	1,5	1,65	1,77	2,2	1,88	2,08	2,24	2,38	2,9	3,36	3,33	4,17	4,3	4,5
8,7	9	9,6	10	10,2	12	13,5	14,5	18,8	19,8	22,4	24,6	26,6	33,4	39,5	—	—	—	—
0,94	1,3	1,3	1,5	1,5	1,5	1,6	—	—	—	—	—	—	—	—	—	—	—	—
2,03	2,8	2,8	3,5	3,6	4,5	4,95	5,3	7	7,52	8,84	9,52	10,1	13	16	22,2	29,2	33,9	46
10,2	14	14	17,5	17,9	21	23	24,8	30,8	33	36,4	39,2	41,6	50,6	58,8	—	—	—	—
—	—	—	—	—	—	0,66	0,71	0,88	1,41	1,56	1,68	1,78	2,17	2,52	3,33	4,17	5	10
—	—	—	—	—	—	1,98	2,12	2,64	2,82	3,12	3,36	3,57	4,34	5,04	6,66	8,34	10,1	12
—	—	—	—	—	—	—	—	—	—	52	56	59,4	72,4	84	111	139	168	200
—	—	—	—	—	—	—	—	—	—	1,04	1,12	1,2	1,45	1,68	2,22	2,78	3,36	4
—	—	—	—	—	—	—	—	—	—	1,56	1,68	1,78	2,17	2,52	3,33	4,17	5	6
—	—	—	—	—	—	—	—	—	—	3,64	3,92	4,16	5,06	5,9	7,8	9,7	11,8	14
—	—	—	—	—	—	—	—	—	—	6,76	7,28	7,73	9,4	10,9	14,4	18,1	21,8	26
—	—	—	—	—	—	—	—	—	—	3,64	3,92	4,16	5,06	5,9	7,8	9,7	11,8	14
—	—	—	—	—	—	—	—	—	—	3,12	3,36	3,57	4,34	5,04	6,7	8,34	10,1	12

Continuation Table 9.12.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлен							
		32	33.5	38	42.3	44.5	45	48	57
(16) Отводы сварные под углом 90°: 16а четырехшовные, $R=1\,D$		—	—	—	—	—	—	—	—
(17) Отводы крутоизогнутые, $R=1{,}5D \div 2D$		0,29	0,3	0,38	0,43	0,48	0,48	0,52	0,65
(18) Отводы гнутые гладкие:									
$R=3\,D$		0,23	0,24	0,3	0,34	0,38	0,39	0,42	0,52
$R>4\,D$		0,17	0,18	0,22	0,26	0,29	0,29	0,31	0,4
(19) Компенсаторы П-образные со сварными трехшовными отводами, $R=1{,}5\,D$		—	—	—	—	—	—	—	—
(20) Компенсаторы П-образные с крутоизогнутыми отводами $R=1{,}5$; $R=2D$		3,1	3,1	3,5	3,7	4	4	4,2	5,2
(21) Компенсаторы П-образные с гнутыми гладкими отводами:									
$R=3\,D$		2,1	2,2	2,4	2,6	2,6	2,7	2,8	3,5
$R>4\,D$		1,7	1,8	1,8	1,9	1,9	2	2,2	2,4
(22) Компенсатор однолинзовый: без рубашки[4]		—	—	—	—	—	—	—	—
(23) с рубашкой		—	—	—	—	—	—	—	—
(24) Тройник при разделении потока:									
(24а) проход[3]		0,57	0,6	0,75	0,86	0,96	0,97	1,04	1,3
(24б) ответвление		0,86	0,9	1,13	1,29	1,44	1,45	1,56	1,96
(25) Тройник при слиянии потока:									
(25а) проход[3]		0,86	0,9	1,13	1,29	1,44	1,45	1,56	1,96
(25б) ответвление		1,14	1,2	1,5	1,72	1,92	1,94	2,08	2,62
(26) Тройники:									
(26а) при расходящемся потоке		1,14	1,2	1,5	1,72	1,92	1,94	2,08	2,62
(27) встречном		1,71	1,8	2,25	2,58	2,88	2,91	3,12	3,93
(28) Переходы сварные по МН 2883–62[4]:									
$F_1/F_0=2$		—	—	—	0,09	0,1	0,1	0,1	0,13
$F_1/F_0=3$		—	—	—	0,13	0,14	0,14	0,16	0,2
$F_1/F_0=4$		—	—	—	0,17	0,19	0,19	0,21	0,26

Continuation Table 9.12.

t_0 при наружных диаметрах труб в мм

60	75.5	76	88.5	89	101.3	108	114	133	140	152	159	168	194	219	273	325	377	426
–	–	–	–	–	–	–	–	–	–	3,12	3,36	3,57	4,34	5,04	6,7	8,34	10,1	12
0.73	1	1	1,25	1,28	1,6	1,65	1,77	2,2	2,35	2,6	2,8	2,97	3,62	4,2	5,55	6,95	8,4	10
0.56	0.8	0,8	1	1,02	1,2	1,32	1,42	1,76	1,88	2,08	2,24	2,38	2,9	3,36	4,4	5,56	6,7	8
0.44	0.6	0,6	0,75	0,76	0.9	0.98	1,06	1,32	1,41	1,56	1,68	1,78	2,17	2,52	3,3	4,17	5,0	6
–	–	–	–	–	–	–	–	–	–	16,7	17,6	18,5	22,1	24,8	33	40	47	55
5.5	6,8	6,8	7,8	7,9	8,8	9,8	10,3	12,5	13,1	14,6	15,4	16	19	23,4	28	34	40	47
3,7	4,9	4,9	5,3	5,4	6,1	6,5	6,9	8,4	8,4	9,3	10	10,5	12,6	14,4	18	22	26	31
2,6	2,9	3,2	3,4	3,5	3,6	3,8	4,3	5,6	5,7	6,1	6,5	6,9	8,4	9,3	11,2	11,5	16	20
–	–	–	–	–	–	5,57	6	7,5	8	8,2	8,4	8,9	10,1	10,9	13,3	13,9	15,1	16
–	–	–	–	–	–	0.33	0.35	0.44	0,47	0,52	0.56	0,59	0,72	0,84	1,1	1,4	1,68	2
1,45	2	2	2,5	2,55	3	3,3	3,54	4,4	4,7	5,2	5,6	5,94	7,24	8,4	11,1	13,9	16,8	20
2,18	3	3	3,78	3,82	4,5	4,95	5,3	6,6	7,05	7,8	8,4	8,9	10,9	12,6	16,7	20,8	25,2	30
2,18	3	3	3,78	3,82	4,5	4,9	5,3	6,6	7,05	7,8	8,4	8,9	10,9	12,6	16,7	20,8	25,2	30
2,9	4	4	5	5,1	6	6,6	7,1	8,8	9,4	10,4	11,2	11,9	14,5	16,8	22,2	27,8	33,6	40
2,9	4	4	5	5,1	6	6,6	7,1	8,8	9,4	10,4	11,2	11,9	14,5	16,8	22,2	27,8	33,6	40
4,35	6	6	7,5	7,65	9	9,8	10,5	13,2	14,1	15,6	16,8	17,8	21,7	25,2	33,3	41,7	50,4	60
0,14	0,2	0,2	0,25	0,26	0,3	0,33	0,35	0,44	0,47	0,52	0,56	0,59	0,72	0,84	1,1	1,4	1,68	2
0,22	0,3	0,3	0,38	0,38	0,9	0,98	1,06	1,32	1,41	1,56	1,68	1,78	2,17	2,52	3,3	4,17	5	6
0,29	0,4	0,4	0,5	0,51	1,5	1,6	1,77	2,2	2,35	2,6	2,8	2,97	3,62	4,2	5,55	6,95	8,4	10

Key: (1). Designation of local resistance. (2). Draft/drawings. (3). Equivalent lengths of local resistance $l_э$ with the outside diameters of tubes in mm. (4). Catch [1].

FOOTNOTE [1]. The equivalent length of catches with constricted passage and guide tube is accepted with coefficient of 2. ENDFOOTNOTE.

(5). Valve/gate. (6). with vertical shaft. (7). oblique. (8). Check valve. (8a). rotary ("flap"). (8b). hoisting. (9). Gasket compensator. (9a). one-way. (10). bilateral. (11). Sludge pan is washing. (12). Branch/removals welded single-seam with angle of 30°. (13). Branch/removals are welded at an angle of 90°. (14). two-seam R = 1 D. (15) three-seam R = 1.5 D. (16). Branch/removals are welded at an angle of 90°. (16a). Four-seam, R = 1 D. (17). Branch/removals sharply bent, R = 1.5 D - 2D. (18). Branch/removals the bent smooth. (19). Compensators U-shaped with welded three-seam branch/removals, R = 1.5 D. (20). Compensators U-shaped with the sharply bent branch/removals = 1.5; R = 2D. (21). Compensators are U-shaped with the bent smooth branch/removals. (22). Compensator is single-lens

(22a). without jacket [2].

FOOTNOTE [2]. The equivalent length of two- and three-lens compensators without jacket are accepted respectively in two or three times more. ENDFOOTNOTE.

(23). with jacket. (24). Tee with the merging/coalescence of flow. (24a). pass [3].

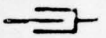
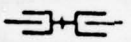
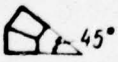
FOOTNOTE [3]. Equivalent length is considered on section with the total consumption of water. ENDFOOTNOTE.

(24b). branch. (26). -piece with the merging/coalescence of flow. (26a). with the diverging flow. (27). contrary. (28). Transfer/transitions welded on MN 2883-62 [4].

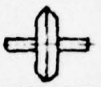
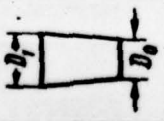
FOOTNOTE [4]. Equivalent length is considered on section with smaller diameter. ENDFOOTNOTE.

Pages 130 and 131.

Table 9.13. Equivalent lengths of local resistance with $k_э$=0.5 mm for tubes D_y=450 ÷ 1200 mm.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений $l_э$ при наружных диаметрах трубы в мм							
		478	529	630	720	820	920	1020	1220
(4) Задвижка		4,7	5,3	5,7	6	6,4	6,8	7,1	7,5
(5) Обратный клапан поворотный („захлопка")		56	66	89,5	112	133	158	180	226
(6) Сальниковый компенсатор: (7) односторонний		11,7	13,1	16,5	19,4	22,8	26,3	30,1	37,6
(8) двусторонний		14	15,8	19,9	23,3	27,4	31,6	36,1	45,1
(9) Грязевик промывочный		233	262	331	388	456	526	602	752
(10) Отводы сварные одношовные с углом: 30°		4,7	5,3	6,6	7,8	9,2	10,5	12	15
45°		7	7,9	9,9	11,7	13,7	15,8	18	22,6
60°		16,3	18,4	23,2	27,2	32	36,8	42,1	52,6
90°		30,3	34,2	43,1	50,4	59,4	68,3	78,2	97,8
(11) Отводы сварные с углом 90°: (12) двухшовные, R=1D		16,3	18,4	23,2	27,2	32	36,8	42,1	52,6
(13) трехшовные, R=1D		16,3	18,4	23,2	27,2	32	36,8	42,1	52,6
(14) трехшовные, R=1,5D		14	15,8	19,9	23,3	27,4	31,6	36,1	45,1

Continuation Table 9.13.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений $l_э$ при наружных диаметрах трубы в мм							
		478	529	630	720	820	920	1020	1220
(14) Отводы сварные с углом 90°: четырехшовные, $R=1D$		14	15,8	19,9	23,3	27,4	31,6	36,1	45,1
(15) Отводы крутоизогнутые, $R=1D$; $R=1,5D$		11,7	13,1	16,5	19,4	22,8	26,3	30,1	37,6
(16) Компенсаторы П-образные со сварными трехшовными отводами: $R=1D$ / $R=1,5D$		78 / 67	89 / 76	110 / 94	126 / 110	147 / 128	166 / 145	188 / 164	230 / 200
(17) Компенсаторы П-образные с крутоизогнутыми отводами, $R=1D$; $R=1,5D$		60	68	83	95	110	124	140	170
(18) Компенсатор однолинзовый:									
(18а) без рубашки[3]		16,3	17,1	19,9	22,5	24,7	26,3	30,1	37,6
(18б) с рубашкой		2,4	2,6	3,3	3,9	4,6	5,3	6	7,5
(19) Тройник при разделении потока:									
(20) проход[3]		23,3	26,3	33,1	38,8	45,7	52,6	60,2	75,2
(21) ответвление		35	39,4	49,6	58,2	68,6	78,8	90,2	113
(22) Тройник при слиянии потока:									
(22) проход[3]		35	39,4	49,6	58,2	68,6	78,8	90,2	113
(21) ответвление		46,6	52,5	66,2	77,6	91,5	105	120	150
(23) Тройники:									
(24) при расходящемся потоке		46,6	52,5	66,2	77,6	91,5	105	120	150
(25) » встречном »		69,9	78,7	99,3	116	137	158	181	226
(26) Переходы сварные[4] (по МН 2883–62):									
$F_1/F_0=2$		2,4	2,6	3,3	3,9	4,6	5,26	6	7,5
$F_1/F_0=3$		4,7	5,3	6,6	7,8	9,2	10,5	12	15
$F_1/F_0=4$		7	7,9	9,9	11,6	13,7	15,8	18	22,6

Note. See footnotes to Table 9.12.

Key: (1). Designation of local resistance. (2). Draft/drawings. (3). Equivalent lengths of local resistance with the outside diameters of tube in mm. (4). Catch [1]. (5). Check valve rotary ("flap"). (6). Gasket compensator. (7). one-way. (8). bilateral. (9). Sludge pan is washing. (10). Branch/removals welded single-seam with angle. (11). Branch/removals welded with angle of 90°. (12). two-seam, R = 1 D. (13). three-seam, R = 1 D. (14). three-seam, R = 1.5 D (15). Branch/removals sharply bent, R = 1 D; R = 1.5 D. (16). Compensators are U-shaped with welded three-seam branch/removals. (17). Compensators U-shaped with sharply bent branch/removals, R = 1 D; R = 1.5 D. ([18]). Compensator is single-lens. ([18]a). without jacket [2]. (18b). with jacket. (19). -piece during the separation of flow. (20). pass [3]. (21). branch. (22). -piece with the merging/coalescence of flow. (23). -pieces. (24). with the diverging flow. (25). with counterflow. (26). Transfer/transitions welded • (according to MN 2883-62).

Table 9.14 Values $\sqrt[4]{\frac{k_A}{k_B}}$.

(1) k_B в мм	k_A в мм					
	0,05	0.1	0,2	0.5	0.8	1
0.05	1	1.19	1.41	1.78	2	2.11
0.1	0.841	1	1.19	1.5	1.68	1.78
0.2	0.707	0.841	1	1.26	1.41	1.5
0.5	0.562	0.669	0,795	1	1.13	1.19
0.8	0.5	0.596	0,707	0.889	1	1.06
1	0.473	0.562	0.669	0.841	0.946	1

Key: (1). in mm.

Page 132.

During hydraulic designs of water thermal grid/networks Specific losses of pressure on friction in pipelines should be accepted:

for the sections of calculated main line from heat source to the most removed user - to 8 kgf/m² m;

for a branch of calculated main line - on the available pressure differential, but not more than 30 kgf/m² m.

Table 9.15. Values of coefficient β for the conversion of specific loss of pressure on friction in the range of quadratic law and equivalent lengths of local resistance at the values of the equivalent roughness, different from $k_э$=0,5 мм.

(1) Наружный диаметр трубы $D_н$ в мм	(2) s в мм	(3) Значения коэффициента β при эквивалентной шероховатости в мм																						
		0.2	0.3	0.4	0,5	0.6	0.7	0.8	0.9	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	3,2	3.4	3,6	3.8	4
32	2.5; 3; 3.5	0,725	0,83	0,92	1	1,07	1,15	1,2	1,27	1,33	1,44	1,55	1,65	1,75	1,86	1,95	2,04	2,14	2,28	2,32	2,41	2,5	2,57	2,68	2,78
38	2,5; 3; 3,5	0,73	0,84	0,92	1	1,07	1,14	1,2	1,26	1,31	1,42	1,52	1,61	1,71	1,79	1,88	1,97	2,05	2,13	2,21	2,29	2,37	2,45	2,53	2,6
45	3,5; 2,5; 3	0,74	0,84	0,93	1	1,07	1,13	1,19	1,24	1,30	1,4	1,49	1,58	1,67	1,75	1,82	1,91	1,99	2,06	2,14	2,21	2,28	2,35	2,43	2,5
57	3; 3,5	0,75	0,85	0,93	1	1,06	1,12	1,18	1,23	1,28	1,38	1,47	1,55	1,63	1,71	1,78	1,85	1,92	2	2,06	2,12	2,19	2,25	2,315	2,38
76	3; 3,5; 4	0,75	0,85	0,93	1	1,06	1,12	1,17	1,22	1,27	1,35	1,43	1,51	1,58	1,65	1,72	1,79	1,85	1,91	1,97	2,03	2,09	2,14	2,2	2,25
89	3,5; 4	0,77	0,86	0,93	1	1,06	1,11	1,16	1,21	1,26	1,34	1,42	1,49	1,56	1,63	1,69	1,755	1,81	1,88	1,93	1,99	2,04	2,09	2,14	2,2
108	4; 4,5	0,77	0,86	0,94	1	1,06	1,11	1,16	1,2	1,25	1,33	1,4	1,47	1,54	1,6	1,66	1,72	1,77	1,83	1,88	1,93	1,98	2,03	2,08	2,13
133	4; 4,5;	0,78	0,87	0,94	1	1,06	1,11	1,15	1,2	1,24	1,32	1,38	1,45	1,51	1,57	1,63	1,68	1,74	1,78	1,84	1,89	1,94	1,98	2,02	2,07
159	4,5; 5	0,78	0,87	0,94	1	1,05	1,1	1,15	1,19	1,23	1,31	1,37	1,44	1,5	1,58	1,61	1,66	1,71	1,76	1,81	1,85	1,89	1,94	1,98	2,02
194	5; 6	0,79	0,87	0,94	1	1,05	1,1	1,14	1,19	1,23	1,3	1,36	1,42	1,48	1,53	1,58	1,63	1,68	1,73	1,77	1,81	1,86	1,9	1,94	1,98
219	6; 7	0,79	0,87	0,94	1	1,05	1,1	1,14	1,18	1,22	1,28	1,35	1,41	1,47	1,52	1,57	1,62	1,67	1,71	1,76	1,80	1,84	1,88	1,91	1,95
273	7; 8; 9	0,80	0,88	0,94	1	1,05	1,1	1,14	1,18	1,21	1,28	1,34	1,4	1,45	1,5	1,55	1,59	1,64	1,68	1,72	1,76	1,8	1,83	1,87	1,91
325	8; 9; 10	0,80	0,88	0,94	1	1,05	1,09	1,13	1,17	1,21	1,27	1,33	1,39	1,44	1,425	1,53	1,57	1,62	1,66	1,7	1,73	1,77	1,8	1,84	1,87
377	9—13	0,80	0,88	0,94	1	1,05	1,09	1,13	1,17	1,2	1,27	1,32	1,38	1,43	1,47	1,52	1,56	1,6	1,64	1,68	1,71	1,75	1,78	1,81	1,85
426	5—13	0,81	0,88	0,95	1	1,05	1,09	1,13	1,17	1,2	1,26	1,32	1,37	1,42	1,46	1,505	1,55	1,59	1,62	1,66	1,69	1,73	1,76	1,79	1,82
478	5—10	0,81	0,89	0,95	1	1,05	1,09	1,12	1,16	1,2	1,25	1,31	1,36	1,41	1,45	1,495	1,53	1,57	1,61	1,64	1,68	1,71	1,74	1,77	1,8
529	6—10	0,81	0,89	0,95	1	1,05	1,09	1,12	1,16	1,19	1,25	1,3	1,36	1,4	1,45	1,49	1,53	1,56	1,6	1,63	1,67	1,7	1,73	1,76	1,79
630	6—10	0,81	0,89	0,95	1	1,04	1,09	1,12	1,16	1,19	1,25	1,3	1,35	1,39	1,43	1,47	1,51	1,55	1,59	1,61	1,65	1,68	1,71	1,74	1,76
720	7—10	0,82	0,89	0,95	1	1,04	1,08	1,12	1,15	1,18	1,24	1,29	1,34	1,38	1,43	1,46	1,5	1,54	1,57	1,6	1,63	1,66	1,69	1,72	1,745
820	7—10	0,82	0,89	0,95	1	1,04	1,08	1,12	1,15	1,18	1,24	1,29	1,33	1,38	1,42	1,45	1,49	1,52	1,56	1,59	1,62	1,65	1,67	1,7	1,73
920	7—11	0,82	0,89	0,95	1	1,04	1,08	1,11	1,15	1,18	1,23	1,23	1,33	1,37	1,41	1,45	1,48	1,51	1,55	1,58	1,61	1,63	1,66	1,69	1,71
1020	8—12	0,82	0,895	0,95	1	1,04	1,08	1,11	1,15	1,17	1,23	1,28	1,32	1,36	1,4	1,44	1,47	1,51	1,54	1,57	1,6	1,62	1,65	1,67	1,7

Key: (1). Outside diameter of tube $D_н$ in mm. (2). in mm. (3). Values of the coefficient β with equivalent roughness in mm.

Table 9.16. Sheet/table/list of the calculated consumption of water by users for hydraulic design of main-line and distributive thermal grid/networks.

(1) № п/п	(2) № по генплану	(3) Потребитель	(4) Расчетный расход воды в т/ч				
			(5) на отопление G_o	(6) на вентиляцию $G_в$ при		(7) на горячее водоснабжение $G_г^р$	(8) суммарный G
				$t_{н.в}$	$t_{н.в} = t_{н.о}$		
1		(9) Промпредприятие	62	8	—	40	110
2	М1	(10) Микрорайон 1	97,5	—	2,5	20	120
3	М2	. 2	65	—	5	20	90
		(11) Итого	224,5	8	7,5	80	320

Key: (1). No in sequence. (2). No on general plan. (3). User. (4). Calculated consumption of water in m/h. (5). for heating G_o. (6). for ventilation $G_в$ with. (7). to hot water supply $G_г^р$. (8). total G. (9). Industrial enterprise. (10). City block. (11). Altogether.

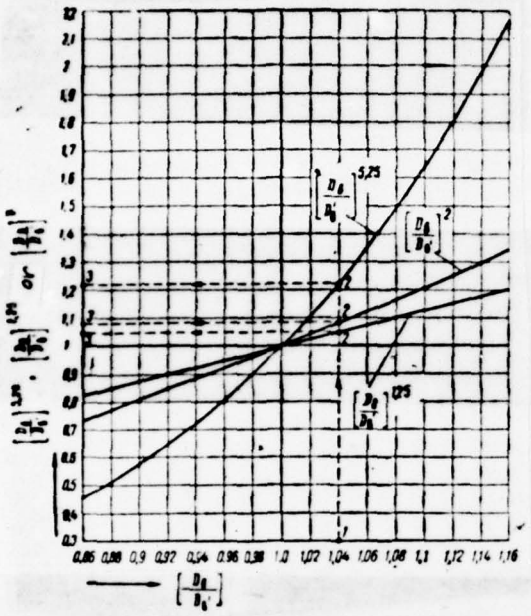


Fig. 9.8. Graph for determining the values $\left[\frac{D_в}{D'_в}\right]^{5.25}$; $\left[\frac{D_в}{D'_в}\right]^{1.25}$ $\left[\frac{D_в}{D'_в}\right]^{2}$

Page 133.

If with the taken specific losses of pressure on friction surplus pressure differential on submains will not

be completely used, the remaining jump/drop is utilized on the input/introductions to users into elevators or is throttled with washers.

For hydraulic calculation of the pipelines of water thermal lines there are compiled sheet/table/list of the calculated consumption of water by users (Table 9.16), in which are brought the calculated consumption of water by each user separately for heating, ventilation, hot water supply and total consumption, and design diagram Fig. 9.9.

If the calculated consumption of water for hot water supply by users (see Section 9-2) for the calculation of main-line, distribution networks and for the calculation of branches they determine from equal formulas, then they compose two sheet/table/lists: one for the calculation of main-line and distribution networks, another - for the calculation of branches to separate buildings.

First of all is designed basic calculated main line from the source of heat to the most removed user.

Designed it should be in form, given in Table 9.17, on the individual sections of pipeline.

An example of calculation for the circuit, given to Fig. 9.9, is given in Table 9.17. The sheet/table/list of the calculated consumption of water is given in Table 9.16.

9.5. HYdraulic design of steam lines.

Hydraulic design of steam lines performs taking into account state change pair because of a drop in the pressure during its motion along pipeline and a temperature drop because of the heat losses in the environment.

State pair is accepted for each calculated section at average/mean specific gravity/weight and mean temperature on this section.

With a sufficient degree of accuracy average specific gravity/weight the pair on section is determined from the formula

$$\gamma_{cp} = \frac{\gamma_a + \gamma_k}{2} \quad kg/m^3. \qquad (9.32)$$

where $\gamma_н$ and $\gamma_к$ – specific gravity/weights pair in the beginning and end of the calculated section in kg/m³.

A temperature drop of the superheated steam on the section of steam line because of heat losses in the environment is determined from the formula

$$\Delta t = \frac{Q \cdot 10^{-3}}{G c_p} °C, \qquad (9.33)$$

where Q is the heat loss into the environment by the section of steam line in kcal/h;

G - calculated consumption is pair on section in t/h;

c_p – the true heat caPacity of the superheated steam at a constant pressure in the average parameters pair on section in kcal/kg deg.

Table 9.17. Form of table and an example of hydraulic design of water thermal grid/networks.

(1) № участков	(2) Расход воды G в т/ч	(3) Характеристика трубы: (8) условный проход D_y в мм	(9) наружный диаметр × толщина стенки в мм $D_н \times s$	(4) Длина участка трубопровода в м: (10) по плану l	(11) эквивалентная местным сопротивлениям $l_э$	(12) приведенная $l_{пр} = l + l_э$	(5) Скорость воды на участке v в м/сек	(6) Потеря давления: (13) удельная на трение Δh в кгс/м² м	(14) на участке $\Delta H = \Delta h l_{пр}$ в кгс/м²	(7) Суммарная потеря давления от ТЭЦ (или котельной) $H = \Sigma \Delta H \cdot 10^{-3}$ в м вод. ст.
(15) *Основная расчетная магистраль*										
ТЭЦ – 1	320	300	325×8	645	195	840	1,24	5,36	4500	4,5
1–2	200	250	273×7	430	130	560	1,1	5,3	2970	7,47
2–1	110	200	219×6	216	64	280	0,95	5,22	1460	8,93
(16) *Ответвления от расчетной магистрали (распределительные сети)*										
2–M2	90	175	194×5	162	48	210	0,98	6,5	1368	8,838
1–M1	120	200	219×6	377	113	490	1,03	6,2	3040	7,54

Key: (1). No sections. (2). Consumption of water G in ~~t/s~~ t/h. (3). Characteristic of tube. (4). Length of the section of pipeline in m. (5). Speed of water on section v in m/s. (6). Loss of pressure. (7). Total loss of pressure from heat and power plant (or boiler) $H = \Sigma \Delta H \cdot 10^{-3}$ in m water column. (8). the internal diameter D_y in m. (9). the outside diameter x wall thickness in mm $D_н \times s$. (10). according to the plan l. (11). equivalent to local resistance $l_э$. (12). given $l_{пр} = l + l_э$. (13). specific for friction Δh in kgf/m² m. (14). on section $\Delta h l_{пр}$ in kgf/m². (15). Basic calculated main line. (16). Branches from calculated main line (distribution networks).

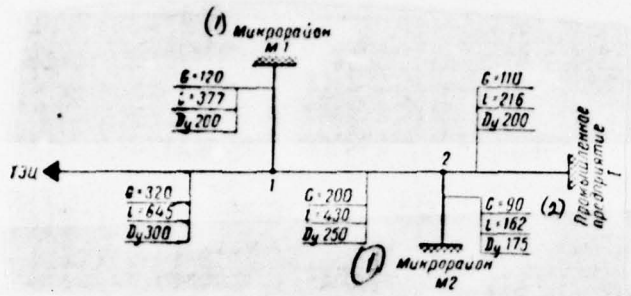


Fig. 9.9. The design diagram of main-line and distributive water thermal grid/networks. In the diagram are given: the consumption of heat carrier G in t/h, length of calculated section l in m and the internal diameter of pipeline D_y in mm.

Key: (1). City block. (2). Industrial enterprise.

Page 134.

The heat loss into the environment is determined from the formula

$$Q = q_{yд}(t_{ср} - t_0)\,l \quad \text{kcal/h}, \qquad (9.34)$$

where l — the length of calculated section in m;

$q_{уд}$ – the specific heat loss by the isolated/insulated steam line taking into account the heat losses by reinforcement, compensators and supports in kcal/m h deg (see Table 9.10).

Specific loss of pressure on friction in steam lines is determined according to the available pressure differential, but at speed pair, not more given in Table 9.18. On branches to separate users, is allow/assumed to increase speed the pair in comparison with the values, indicated in Table 9.18, but it is not more than 1.3 times.

The available specific loss of pressure on friction is determined from the formula

$$\Delta h^p = \frac{H^p}{l_{пр}} \text{ kg/m}^2 \text{ m}, \qquad (9.35)$$

where $l_{пр}$ – the reduced length of pipeline in m;

H^p – the available loss of pressure on friction and local resistance in kgf/m^2.

The available loss of pressure on friction and local resistance is determined from the formula

$$H^{p} = (P_1 - P_2)\,10^4 \quad \text{kg/m}^2 \quad \text{m}, \tag{9.36}$$

where P_1 and P_2 - assigned/prescribed initial and stagnation pressure is pair in kg/cm².

Hydraulic design of steam lines can be performed on Table 9.19 and nomograms Fig. 9.10 and Fig. 9.11. The values of the equivalent lengths of local resistance are given in Tables 9.20 and 9..21.

During the compilation of tables and to nomograms it is accepted: temperature pair t = 300°C, pressure pair P = 13 kg/cm², specific gravity/weight pair γ = 1 kG/m³ (conditionally), equivalent roughness $k_э = 0{,}2$ mm and dynamic viscosity μ = 2.05•10⁻⁶ kgf s/m².

At the values of equivalent roughnesses and tube bores, which differ from the taken during compilation tables and nomograms, values Δh, v and $l_э$ obtained from tables or

nomograms, they recount by formulas (9.25), (9.26), (9.29)-(9.31). Real specific losses of pressure on friction $\Delta h_д$ and speeds pair $v_д$ with calculated average/mean specific gravity/weight pair $\gamma_{ср}$, not equal to unity, are determined from the formulas:

$$\Delta h_д = \frac{\Delta h}{\gamma_{ср}} \text{ (1) } кгс/м^2 \cdot м; \qquad (9.37)$$

$$v_д = \frac{v}{\gamma_{ср}} \text{ (2) } м/сек. \qquad (9.38)$$

Key: (1). kgf/m² m. (2). m/s.

Table 9.18. Recommended maximum speeds pair in steam lines in m/s.

(1) Условный проход труб D_y в мм	(2) Перегретый пар	(3) Насыщенный пар
(4) До 200 мм	80	35
(5) Выше 200 .	80	60

Key: (1). The internal diameter of tubes D_y in mm. (2). The superheated steam. (3). The saturated steam. (4). To 200 mm. (5). Above 200 mm.

Page 135.

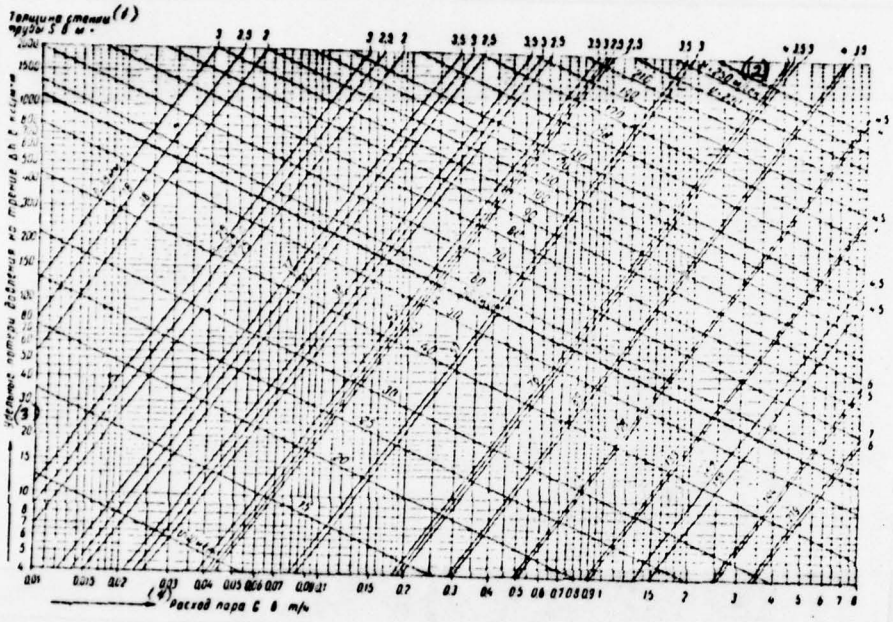


Fig. 9.10. Nomogram for hydraulic design of steam lines with $k_э = 0{,}2$ mm and γ = 1 kG/m³ with consumption pair from 0.01 to 8 t/hs. Bold line designates the maximum speed $v_{пр} = 56.3$ m/s, which corresponds to the boundary/interface between the transfer and quadratic range.

Key: (1). The wall thickness of tube S in m. (2). m/s. (3). Specific losses of pressure to friction Δh in kg/m³ m. (4). Consumption is pair G in t/h.

Page 136.

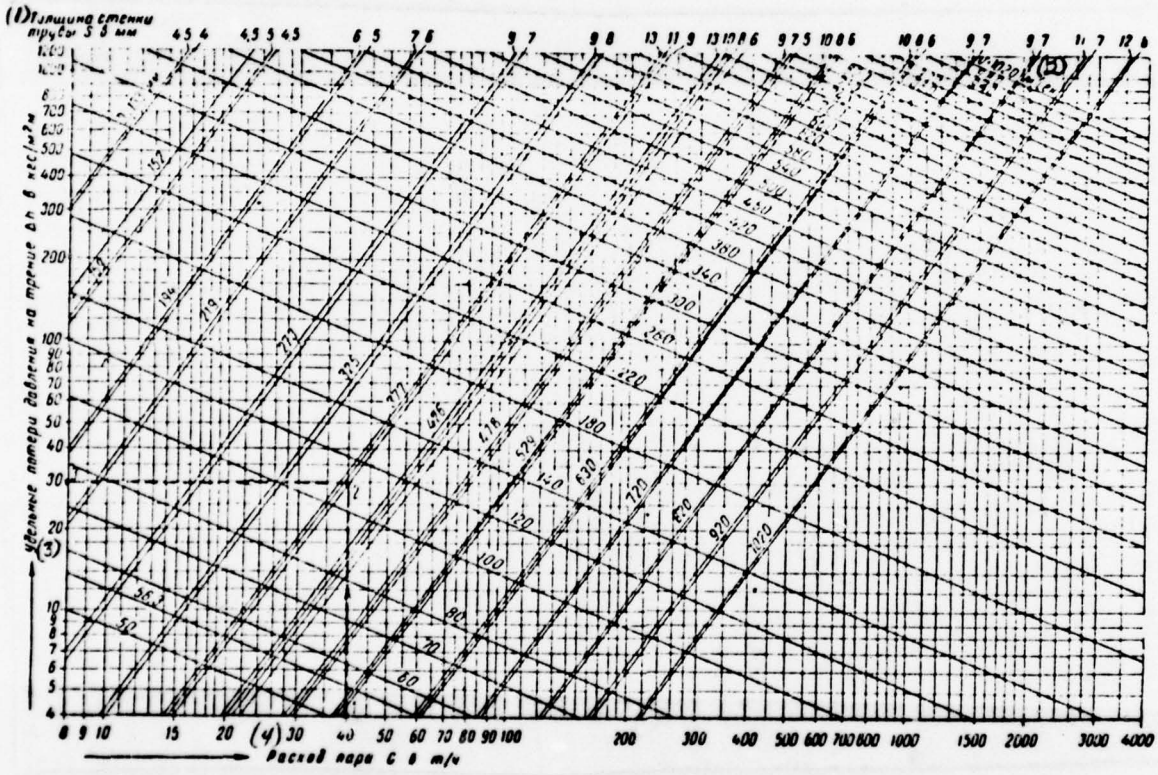


Fig. 9.11. Nomogram for hydraulic design of steam lines with $k_э$=0,2 mm and γ = 1 kG/m³ with consumption pair from 8 to 4000 t/h.

Example. It is given to G = 40 t/h ; $D_н$ = 377 mm; s = 9 mm; P = 8 kg/cm²; t = 250°C; $\gamma_{ср}$ = 3,35 kg/m³. We find in point 2 v = 110 m/s, and in point 3 Δh = 29.3 kgf/m² m. We determine actual values $\Delta h_д = \frac{\Delta h}{\gamma_{ср}} = \frac{29,3}{3,35} = 8,75$ kgf/m² m; $v_д = \frac{v}{\gamma_{ср}} = \frac{110}{3,35} = 32,8$ m/s.

Key: (1). The wall thickness of tube S in mm. (2). m/s. (3). Specific losses of pressure on friction Δh in kgf/m² m. (4). Consumption is pair G in t/h.

Pages 137-143.

Table 9.19. Hydraulic design of steam lines with $k_э$=0,2 mm and γ = 1 kG/m³.

$D_н \times s$ мм (1)	32×2,5		38×2,5		44,5×2,5		45×2,5		57×3,5		76×3,5		89×3,5	
(2) $G_в$ т/ч	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м	(3) $v_в$ м/сек	(4) $\Delta h_в$ кгс/м²м
0,02	9,71	7,0												
0,03	14,6	1,2	9,75	5,2										
0,04	19,4	26	13	9,9	9,08	3,7	8,85	3,5						
0,05	24,3	40	16,3	15,3	11,3	5,6	11,1	5,2						
0,06	29,1	57	19,5	21,9	13,6	8	13,3	7,5						
0,07	34	77	22,8	29	15,9	10,8	15,5	10,1						
0,08	38,8	99	26	37	18,2	14	17,7	13,1						
0,09	43,7	127	29,3	46	20,4	18,8	19,9	16,5	12,7	5,2				
0,1	48,6	153	32,5	58	22,7	21,5	22,1	20,3	14,2	6,4				
0,11	53,4	185	35,8	67	25	26	24,3	24,5	15,6	7,7				
0,12	58,3	220	39	80	27,2	31	26,6	28,8	17	9,1	8,92	1,68		
0,13	63,1	258	42,3	94	29,5	36	28,8	34	18,4	10,3	9,67	2		
0,14	68	299	45,5	108	31,8	42	31	39	19,8	12,1	10,4	2,27		
0,15	72,8	343	48,8	120	34,0	47	33,2	45	21,2	14	11,2	2,38		
0,16	77,7	390	52	135	36,3	53	35,4	50	22,7	15,9	11,9	2,6		
0,17	82,6	441	55,3	152	38,6	60	37,6	57	24,1	18	12,6	3,3	8,95	1,4
0,18	87,4	494	58,5	170	40,8	67	39,8	64	25,5	20	13,4	3,65	9,48	1,57
0,19	92,3	550	61,8	189	43,1	75	42	70	26,9	22	14,1	4	10	1,65
0,2	97,1	610	65	210	45,4	83	44,3	78	28,3	24	14,9	4,5	10,5	1,97
0,22	107	738	71,5	254	49,9	100	48,7	94	31,2	29	16,4	5,3	11,6	2,25
0,24	117	878	78	302	54,5	117	53,1	112	34	35	17,8	6,4	12,6	2,72
0,26	126	1031	84,5	355	59	137	57,5	128	36,8	40	19,3	7,5	13,7	3,15
0,28	136	1195	91	411	63,5	158	62	148	39,6	46,1	20,8	9	14,7	3,68
0,3	146	1372	97,5	412	68,1	182	66,4	170	42,5	54	22,3	9,8	15,8	4,13
0,32	155	1561	104	537	72,6	207	70,8	194	45,3	61	23,8	10,2	16,8	4,7
0,34	165	1762	111	606	77,1	234	75,2	218	48,1	68	25,3	12,8	17,9	5,2
0,36	175	1976	117	680	81,7	262	79,7	245	51	75	26,8	14,2	19	5,8
0,38	185	2201	124	757	86,2	292	84,1	273	53,8	84	28,3	16	20	6,5
0,4	194	2439	130	839	90,8	323	88,5	302	56,6	92,7	29,7	17,8	21,1	7,1
0,42	204	2689	137	925	95,3	356	93	332	59,5	102	31,2	19,5	22,1	7,8

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Continuation Table 9.19.

(1) $D_н \times s$ в мм	44,5×2,5		45×2,5		57×3,5		76×3,5		89×3,5		108×4		133×4		152×4,5		159×4,5	
G в т/ч (2)	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
0,44	99,8	391	97,4	365	62,3	112	32,7	21,5	23,2	8,8								
0,46	104	427	102	400	65,1	123	34,2	23	24,2	9,5	16,3	3,42						
0,48	109	465	106	435	68	134	35,7	25	25,3	10,1	17	3,8						
0,5	113	505	111	472	70,8	145	37,1	27	26,3	11	17,7	4						
0,55	125	611	122	572	77,9	175	40,9	33	29	13,15	19,5	4,8						
0,6	136	727	133	680	85	209	44,6	39	31,6	15,3	21,2	5,7						
0,65	147	853	144	708	92	245	48,3	45	34,3	18,3	23	6,7						
0,7	159	990	155	926	99,1	284	52	53	36,9	21	24,8	7,7						
											26,6	9						
0,75	170	1136	166	1063	106	326	55,8	61,5	39,5	24								
0,8	182	1293	177	1209	113	371	59,5	67,6	42,1	27,2	28,3	9,8	18,1	3,2				
0,85			188	1365	120	419	63,2	76,3	44,8	30,7	30,1	11,2	19,3	3,61				
0,9					127	469	66,9	85,5	47,4	34,5	31,9	12,7	20,4	4				
0,95					135	523	70,6	95,3	50	38,3	33,6	14	21,5	4,41				
1					142	579	74,4	105	52,6	42,5	35,4	15,1	22,7	4,9				
											37,2	17	23,8	5,32				
1,05					149	639	78,1	116	55,3	46								
1,1					156	701	81,8	128	57,9	51,4	38,9	18,5	24,9	5,9				
1,15					163	765	85,5	140	60,5	56,2	40,7	20,1	26,1	6,4				
1,2					1,7	834	89,2	152	63,2	61,2	42,5	22	27,2	7	20,8	3,5	18,9	2,7
1,25					177	905	92,9	165	65,8	66,4	44,3	24	28,3	7,5	21,6	3,8	19,7	2,93
1,3					184	979	96,7	178	68,4	71,8	46	26	29,5	8,3	22,5	4,07	20,5	3,19
1,35					191	1056	100	192	71,1	77,4	47,8	28	30,6	9	23,4	4,4	21,2	3,39
1,4					198	1136	104	207	73,7	83,2	49,6	29,5	31,7	9,5	24,7	4,7	22	3,65
1,45							108	222	76,3	89,3	51,3	32	32,9	10,1	25,1	5	22,8	3,96
1,5							112	238	79	95,6	53,1	34	34	10,6	26	5,32	23,6	4,13
1,55							115	254	81,6	102	54,9	36	35,1	11,3	26,8	5,63	24,4	4,42
											56,6	38,2	36,2	12,1	27,7	6,1	25,2	4,71
1,6							119	270	84,2	109	58,4	40,6	37,3	12,9	28,6	6,4	26	5
1,65							123	287	86,9	116	60,2	43,1	38,5	13,7	29,4	6,78	26,7	5,3
1,7							126	305	89,5	123	62	45,6	39,6	14,6	30,3	7,25	27,5	5,64
1,75							130	323	92,2	130	63,7	48,4	40,8	15,2	31,2	7,7	28,3	6,01
1,8							134	342	94,8	138								

Continuation Table 9.19.

(1) $D_н \times s$ в мм	76×3,5		89×3,5		108×4		133×4		152×4,5	
G (2) в т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
1,85	138	361	97,4	145	65,5	51	41,9	16	32,1	8
1,9	141	381	100	153	67,3	53,9	43	16,8	32,9	8,5
1,95	145	401	103	161	69,1	56,8	44,2	17,8	33,8	9
2	149	422	105	170	70,8	59,7	45,3	18,8	34,6	9,51
2,1	156	466	111	187	74,3	65,8	47,6	20,6	36,4	10,35
2,2	164	511	116	206	77,9	72,2	49,8	22,5	38,1	11,2
2,3	171	559	121	225	81,4	79	52,1	24,5	39,8	12,2
2,4	178	608	126	245	85	86	54,4	26,6	41,5	13,3
2,5	186	660	132	265	88,5	93,3	56,6	28,8	43,3	14,4
2,6	193	714	137	287	92	101	58,9	31,8	45	15,5
2,7	201	770	142	310	95,6	109	61,2	33,6	46,7	16,7
2,8	208	828	147	333	99,1	117	63,4	36,2	48,5	18
2,9	216	888	153	357	103	126	65,7	38,8	50,2	19,2
3	223	950	158	382	106	134	68	41,5	51,9	20,5
3,1	230	1015	163	408	110	143	70,2	44,3	53,7	21,9
3,2	238	1081	168	435	113	153	72,5	47,2	55,4	23,3
3,3	245	1150	174	462	117	163	74,8	50,2	57,1	24,8
3,4	253	1221	179	491	120	173	77	53,3	58,9	26,3
3,5	260	1293	184	520	124	183	79,3	56,5	60,6	27,9
3,6			190	550	127	193	81,6	60	62,3	29,5
3,7			195	581	131	204	83,8	63,2	64,1	31,1
3,8			200	613	135	216	86,1	66,6	65,8	32,8
3,9			205	646	138	227	88,4	70,2	67,5	34,6
4			211	680	142	239	90,6	73,8	69,2	36,4
4,2			221	749	149	263	97,4	85,3	72,7	40,1
4,4			232	822	156	289	99,7	89,3	76,2	44
4,6			242	899	163	316	104	97,6	79,6	48,1
4,8			253	978	170	344	109	106	83,1	52,4
5			263	1062	177	373	113	115	86,6	56,9
5,2			274	1148	184	404	118	125	90	61,5

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Continuation Table 9.19.

(1) $D_н \times s$, мм	159×4,5		194×6		194×5		219×7		219×6	
(2) G, кг/с	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²
1,85	29,1	6,3	19,8	2,32	19,4	2,2				
1,9	29,9	6,6	20,3	2,42	19,9	2,25				
1,95	30,7	6,94	20,9	2,68	20,4	2,46				
2	31,5	7,287	21,4	2,7	20,9	2,6				
2,1	33	8,04	22,4	2,95	22	2,8				
2,2	34,6	8,85	23,5	3,22	23	3,1				
2,3	36,2	9,65	24,6	3,51	24	3,32				
2,4	37,8	10,5	25,6	3,8	25,1	3,61	20,2	2,15		
2,5	39,3	11,3	26,7	4,19	26,1	3,94	21,1	2,35	20,7	2,22
2,6	40,9	12,2	27,8	4,44	27,2	4,23	21,9	2,52	21,5	2,4
2,7	42,5	13,2	28,9	4,79	28,2	4,57	22,7	2,7	22,3	2,6
2,8	44,1	14,1	29,9	5,2	29,3	4,86	23,6	2,9	23,1	2,78
2,9	45,6	14,8	31	5,5	30,3	5,2	24,4	3,1	24	2,9
3	47,2	16	32,1	5,9	31,4	5,6	25,3	3,24	24,8	3,1
3,1	48,8	17,1	33,1	6,3	32,4	5,93	26,1	3,5	25,6	3,28
3,2	50,3	18,3	34,2	6,7	33,5	6,3	27	3,72	26,4	3,55
3,3	51,9	19,4	35,3	7,1	34,5	6,7	27,8	3,93	27,3	3,78
3,4	53,5	20,5	36,3	7,52	35,6	7,12	28,6	4,2	28,1	4
3,5	55,1	21,7	37,4	8	36,5	7,52	29,5	4,44	29	4,28
3,6	56,6	22,9	38,5	8,5	37,6	8	30,3	4,7	30	4,5
3,7	58,2	24,2	39,5	8,9	38,7	8,5	31,2	4,82	30,6	4,7
3,8	59,8	25,6	40,6	9,45	39,7	8,9	32	5,15	31,4	5
3,9	61,4	26,9	41,7	9,95	40,8	9,4	32,9	5,4	32,2	5,28
4	62,9	28,3	42,7	10,16	41,8	9,8	33,7	5,8	33	5,55
4,2	66,1	31,2	44,9	11,5	43,9	10,8	35,4	6,35	34,7	6
4,4	69,2	34,3	47	12,5	46	11,9	37,1	6,9	36,4	6,6
4,6	72,4	37,4	49,1	13,6	48,1	12,9	38,7	7,5	38	7,15
4,8	75,5	40,8	51,3	14,8	50,2	14	40,4	8,2	39,7	7,8
5	78,7	44,2	53,4	16,1	5[illegible],3	15,25	42,1	9	41,3	8,6
5,2	81,8	47,9	55,6	17,3	54,4	16,42	43,8	9,6	43	9,2

Continuation Table 9.19.

(1) $D_н \times s$, мм	108×4		133×4		152×4,5		159×4,5		194×6		194×5		219×7	
(2) G, кг/с	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²	(3) v, м/сек	(4) Δh, кгс/м²
5,4	191	435	122	135	93,5	66,3	85	51,6	57,7	18,7	56,5	17,7	45,5	10,2
5,6	198	468	127	145	97	71,3	88,1	55,5	59,8	20,1	58,6	19	47,2	11
5,8	205	502	131	155	100	76,5	91,3	59,5	62	21,6	60,6	20,4	48,9	12
6	212	537	136	165	104	81,9	94,4	63,7	64,1	23,1	62,7	21,8	50,5	12,6
6,2	219	574	140	177	107	87,4	97,5	68	66,3	24,7	64,8	23,3	52,2	13,3
6,4	227	611	145	189	111	93,2	101	72,5	68,4	26,3	66,9	24,8	53,9	14,15
6,6	234	650	150	201	114	99,1	104	77,1	70,5	27,9	69	26,4	55,6	15
6,8	241	690	154	213	118	105	107	81,8	72,7	29,7	71,1	28	57,3	15,9
7	248	731	159	226	121	111	110	86,7	74,8	31,4	73,2	29,7	59	16,8
7,5	266	840	170	259	130	128	118	99,5	80,2	36,1	78,4	34,2	63,2	19,4
8	283	955	181	295	138	146	126	113	85,5	41	83,6	38,8	67,4	22
8,5	301	1078	193	333	147	164	134	128	90,8	46,3	88,9	43,8	71,6	24,8
9	319	1209	204	374	156	184	142	143	96,2	51,9	94,1	49,1	75,8	27,8
9,5			215	416	164	205	149	160	102	57,9	99,3	54,7	80	31
10			227	461	173	227	157	177	107	64,1	105	60,6	84,2	34,4
10,5			238	509	182	251	165	195	112	70,7	110	66,8	88,4	37,9
11			249	558	190	275	173	214	118	77,6	115	73,3	92,7	41,6
11,5			261	610	199	301	181	234	123	84,8	120	80,1	96,9	45,4
12			272	664	208	328	189	255	128	92,4	125	87,2	101	49,5
12,5			283	721	216	355	197	277	134	100	131	94,6	105	53,7
13			295	780	225	384	205	299	139	108	136	102	110	58,1
13,5			306	841	234	415	212	323	144	117	141	110	114	62,6
14			317	904	242	446	220	347	150	126	146	119	118	67,3
14,5			329	970	251	478	228	372	155	135	152	127	122	72,2
15			340	1038	260	512	236	398	160	144	157	136	126	77,3
16			362	1181	277	582	252	453	171	164	167	155	135	88
17			385	1333	294	657	267	511	182	185	178	175	143	99,3
18			408	1494	312	737	283	573	192	208	188	196	152	111
19			430	1655	329	821	299	639	203	232	199	219	160	124
20			453	1845	346	910	315	708	214	257	209	242	168	137

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Continuation Table 9.19.

(1) $D_н \times s$, мм	219×6		273×8		273×7		325×9		325×8		377×10		377×9	
(2) G в т/ч	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг
5,4	44,6	9,8	28,9	3,31	28,5	3,06								
5,6	46,3	10,4	30	3,42	29,6	3,28								
5,8	47,9	11,3	31,1	3,66	30,6	3,52								
6	49,6	11,95	32,2	3,92	31,7	3,77								
6,2	51,2	12,6	33,2	4,16	32,7	4,02								
6,4	52,9	13,6	34,3	4,44	33,8	4,29								
6,6	54,5	14,4	35,4	4,7	34,8	4,53								
6,8	56,2	15,1	36,4	5	35,9	4,8								
7	57,8	16	37,5	5,28	36,9	5,07	26,3	2,09	26	2,02				
7,5	62	18,4	40,2	6,06	39,6	5,82	28,2	2,4	27,9	2,31				
8	66,1	20,9	42,9	6,82	42,2	6,57	30	2,72	29,7	2,62				
8,5	70,2	23,6	45,6	7,64	44,9	7,36	31,9	3,03	31,5	2,96				
9	74,4	26,5	48,2	8,58	47,5	8,27	33,8	3,44	33,4	3,32				
9,5	78,5	29,5	50,9	9,51	50,1	9,15	35,7	3,81	35,2	3,67				
10	82,6	32,7	53,6	10,57	52,8	10,1	37,6	4,23	37,1	4,08				
10,5	86,7	36	56,3	11,6	55,4	11,2	39,4	4,66	38,9	4,5	29,2	2,16	28,8	2,1
11	90,9	39,5	59	12,7	58	12,2	41,3	5,1	40,8	4,92	30,6	2,37	30,2	2,31
11,5	95	43,2	61,6	13,9	60,7	13,3	43,2	5,56	42,6	5,37	31,9	2,6	31,6	2,53
12	99,1	47	64,3	15,1	63,3	14,5	45,1	6,04	44,5	5,83	33,3	2,79	33	2,7
12,5	103	51	67	16,4	66	15,8	47	6,52	46,3	6,3	34,7	3,02	34,3	2,93
13	107	55,2	69,7	17,8	68,6	17,1	48,8	7,07	48,2	6,82	36,1	3,11	35,7	3,17
13,5	112	59,5	72,4	19,2	71,2	18,4	50,7	7,55	50,1	7,35	37,5	3,52	37,1	3,42
14	116	64	75	20,6	73,9	19,8	52,6	8,12	51,9	7,88	38,9	3,77	38,5	3,65
14,5	120	68,7	77,7	22,1	76,5	21,2	54,5	8,74	53,8	8,43	40,3	4,05	39,8	3,91
15	124	73,5	80,4	23,7	79,2	22,7	56,3	9,33	55,6	9	41,7	4,31	41,2	4,18
16	132	83,6	85,8	26,9	84,4	25,8	60,1	10,6	59,3	10,3	44,4	4,91	43,9	4,76
17	140	94,4	91,1	30,4	89,7	29,2	63,9	12	63	11,6	47,2	5,5	46,7	5,38
18	149	106	96,5	34,1	95	32,7	67,6	13,4	66,7	13	50	6,16	49,4	5,98
19	157	118	102	37,9	100	36,4	71,4	15	70,4	14,5	52,8	6,85	52,2	6,64
20	165	131	107	42	106	40,4	75,1	16,6	74,2	16	55,6	7,55	54,9	7,32

Continuation Table 9.19.

(1) $D_н \times s$, мм	194×6		194×5		219×7		219×6		273×8		273×7		325×9		325×8		377×10	
(2) G в т/ч	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг	(3) $\Delta p_в$, кгс/см²	(4) $\Delta h_в$, кгс·м/кг
21	224	283	220	267	177	152	173	144	113	46,4	111	44,5	78,9	18,3	77,9	17,7	58,3	8,3
22	235	310	230	293	185	166	182	158	118	50,9	116	48,9	82,6	20,1	81,6	19,4	61,1	9,1
23	246	339	240	320	194	182	190	173	123	55,6	121	53,4	86,4	21,9	85,3	21,2	63,9	10
24	256	369	251	349	202	198	198	188	129	60,5	127	58,1	90,1	23,9	89	23,1	66,7	10,8
25	267	401	261	379	211	215	207	204	134	65,7	132	63,1	93,9	25,9	92,7	25	69,4	11,8
26	278	434	272	409	219	232	215	221	139	71,1	137	68,2	97,7	28	96,4	27,1	72,2	12,7
27	289	468	282	441	227	250	223	238	145	76,6	142	73,6	101	30,2	100	29,2	75	13,7
28	299	503	293	475	236	269	231	256	150	82,4	148	79,1	105	32,5	104	31,4	77,8	14,8
29	310	539	303	509	244	289	240	275	155	88,4	153	84,9	109	34,9	108	33,7	80,6	15,8
30	321	577	314	545	253	309	248	294	161	94,6	158	90,8	113	37,3	111	36,1	83,3	16,9
31	331	616	324	582	261	330	256	314	166	101	164	97	116	39,8	115	38,5	86,1	18,1
32	342	657	335	620	270	352	264	334	172	108	169	103	120	42,5	119	41	88,9	19,3
33	353	698	345	660	278	374	273	356	177	114	174	110	124	45,1	122	43,6	91,7	20,5
34	363	741	356	700	286	397	281	377	182	122	179	117	128	47,9	126	46,3	94,4	21,8
35	374	786	366	742	295	421	289	400	188	129	185	124	131	50,9	130	49,1	97,2	23,1
36	385	831	376	785	303	445	297	423	193	136	190	131	135	53,7	133	51,9	100	24,4
37	395	878	387	829	312	470	306	447	198	144	195	138	139	56,8	137	54,9	103	25,8
38	406	926	397	874	320	496	314	472	204	152	201	146	143	59,9	141	57,9	106	27,2
39	417	975	408	921	329	523	322	497	209	160	206	154	146	63,1	145	60,9	108	28,6
40	427	1028	418	969	337	550	330	522	214	168	211	161	150	66,3	148	64,1	111	30,1
41	438	1078	429	1018	345	578	339	549	220	177	216	170	154	69,7	152	67,4	114	31,7
42	449	1131	439	1068	354	606	347	576	225	185	222	178	158	73,1	156	70,7	11,7	33,2
43	460	1185	450	1120	362	635	355	604	230	194	227	187	162	76,7	159	74,1	11,9	34,8
44	470	1241	460	1172	371	665	364	632	236	203	232	195	165	80,3	163	77,6	12,2	36,5
45			471	1226	379	696	372	661	241	213	237	204	169	83,9	167	81,1	12,5	38,1
46					387	727	380	691	247	222	243	214	173	87,7	171	84,8	12,8	40
47					396	759	388	721	252	232	248	223	177	91,6	174	88,5	13,1	41,6
48					404	792	397	752	257	242	253	233	180	95,5	178	92,3	13,3	43,4
49					413	825	405	784	263	252	259	242	184	99,5	182	96,2	13,6	45,2
50					421	859	413	816	268	263	264	252	288	104	185	100	13,9	47,1

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Continuation Table 9.19.

$D_н \times s$ мм (1)	377×9		426×11		426×10		426×7		426×6		478×7		478×6		529×7		529×6	
G (2) кг/м	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²
21	57,7	8,1	45,5	4,45	45,1	4,35	43,8	4,04	43,4	3,92	41,5	2,17	34,2	2,12				
22	60,4	8,9	47,7	4,83	47,2	4,76	45,9	4,43	45,4	4,3	36,2	2,39	35,9	2,32				
23	63,2	9,7	49,9	5,34	49,4	5,18	48	4,83	47,5	4,69	37,8	2,62	37,5	2,54				
24	65,9	10,5	52,1	5,75	51,5	5,61	50,1	5,25	49,6	5,1	39,5	2,84	39,1	2,76				
25	68,7	11,4	54,2	6,2	53,7	6,05	52,1	5,65	51,6	5,51	41,1	3,06	40,8	2,98				
26	71,4	12,4	56,4	6,7	55,8	6,5	54,2	6,07	53,7	5,9	42,8	3,31	42,4	3,23				
27	74,2	13,3	58,6	7,2	58	7	56,3	6,5	55,8	6,35	44,4	3,57	44	3,49	46	2,1	35,8	2,07
28	76,9	14,3	60,7	7,7	60,1	7,5	58,4	7	57,8	6,8	46	3,82	45,6	3,74	37,4	2,27	37,1	2,21
29	79,7	15,4	62,9	8,3	62,3	6,2	60,5	7,5	59,9	7,3	47,7	4,11	47,3	4	38,7	2,12	38,4	2,38
30	82,4	16,5	65,1	8,9	64,4	6,4	62,6	8	62	7,8	49,3	4,3	48,9	4,27	40	2,59	39,7	2,55
31	85,1	17,6	67,2	9,5	66,6	9,2	64,7	8,6	64	8,3	51	4,66	50,5	4,56	41,4	2,76	41,1	2,71
32	87,9	18,7	69,4	10,1	68,7	9,8	66,7	9,1	66	8,9	52,6	4,93	52,2	4,82	42,7	2,94	42,4	2,89
33	90,6	19,9	71,6	10,7	70,9	10,5	68,8	9,7	68,1	9,4	54,3	5,21	53,8	5,1	44	3,11	43,7	3,05
34	93,4	21,1	73,7	11,4	73	11,1	70,9	10,3	70,2	10	55,9	5,55	55,4	5,42	45,4	3,31	45	3,25
35	96,1	22,4	75,9	12,1	75,2	11,8	73	10,9	72,3	10,6	57,5	5,9	57,1	5,7	46,7	3,49	46,4	3,43
36	98,9	23,7	78,1	12,8	77,3	12,5	75,1	11,5	74,4	11,3	59,2	6,2	58,7	6,1	48	3,68	47,7	3,62
37	102	25,0	80,2	13,5	79,5	13,2	77,2	12,2	76,4	11,9	60,8	6,6	60,3	6,4	49,4	3,86	49	3,8
38	104	26,4	82,4	14,2	81,6	13,9	79,2	12,9	78,5	12,5	62,5	6,9	61,9	6,8	50,7	4,1	50,3	4,01
39	107	27,8	84,6	15	83,8	14,6	81,3	13,5	80,6	13,2	64,1	7,3	63,6	7,1	52,1	4,28	51,7	4,57
40	110	29,3	86,8	15,8	85,9	15,4	83,4	14,3	82,6	13,9	65,8	7,7	65,2	7,5	53,4	4,48	53	4,4
41	113	30,7	88,9	16,6	88,1	16,2	85,5	15	84,7	14,6	67,4	8	66,8	7,9	54,7	4,65	54,3	4,59
42	115	32,3	91,1	17,4	90,2	17	87,6	15,7	86,7	15,3	69,1	8,4	68,5	8,3	56,1	4,9	55,6	4,8
43	118	33,8	93,3	18,2	92,3	17,8	89,7	16,5	88,8	16,1	70,7	8,8	70,1	8,7	57,4	5,1	56,9	5
44	121	35,4	95,4	19,1	94,5	18,6	91,8	17,2	90,9	16,8	72,3	9,3	71,7	9,1	58,7	5,4	58,3	5,3
45	124	37	97,6	20	96,6	19,5	93,8	18	92,9	17,6	74	9,7	73,4	9,5	60,1	5,6	59,6	5,5
46	126	38,7	99,8	20,9	98,8	20,3	95,9	18,8	95	18,4	75,6	10,1	75	9,9	61,4	5,9	61,9	5,8
47	129	40,4	102	21,8	101	21,2	98	19,7	97,1	19,2	77,3	10,6	76,6	10,3	62,7	6,1	62,2	6
48	132	42,1	104	22,7	103	22,2	100	20,5	99,1	20	78,9	11	78,2	10,8	64,1	6,4	63,5	6,3
49	135	43,9	106	23,7	105	23,1	102	21,4	101	20,9	80,6	11,5	80	11,2	65,4	6,7	64,9	6,5
50	137	45,7	108	24,7	107	24	104	22,3	103	21,7	82,2	12	81,5	11,7	66,7	6,9	66,2	6,8

Continuation Table 9.19.

$D_н \times s$ мм (1)	273×8		273×7		325×9		325×8		377×10		377×9		426×11		426×10		426×7		426×6	
G (2) кг/м	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²	v (3) м/сек	Δh (4) кгс/м²
52	279	284	274	273	195	112	193	108	114	50,9	143	40,5	113	26,7	112	25	108	24,1	107	23,5
54	289	307	285	294	203	121	200	117	153	54,9	148	53,3	117	28,8	116	28	113	26	112	25,3
56	300	330	296	317	210	130	208	126	155	59,1	154	57,4	121	30,9	120	30,2	117	27,9	116	27,2
58	311	354	303	340	218	139	215	135	161	63,4	159	61,5	125	33,2	125	32,4	121	30	120	29,2
60	322	378	317	363	225	149	222	144	167	67,8	165	65,8	130	35,5	129	34,6	125	32,1	124	31,3
62	332	401	327	388	233	159	230	154	172	72,4	170	70,3	134	37,9	133	37	129	34,3	128	33,4
64	343	431	338	413	240	170	237	161	178	77,1	176	74,9	139	40,4	137	39,4	133	36,5	132	35,6
66	354	456	348	440	248	181	245	175	183	82	181	79,7	143	43	142	41,9	138	38,8	135	37,8
68	365	486	359	467	255	192	252	185	189	87,1	187	84,6	147	45,6	146	44,5	142	41,2	140	40,2
70	375	515	369	495	263	203	260	196	194	92,3	192	89,6	152	48,4	150	47,1	146	43,6	145	42,6
72	386	545	380	523	270	215	267	208	200	97,6	198	94,8	156	51,2	155	49,9	150	45,2	149	45
74	397	576	391	553	278	227	274	219	205	103	203	100	160	54	159	52,5	154	48,8	153	47,6
76	407	607	401	583	285	239	282	231	211	109	209	105	165	57	163	55,5	158	51,4	157	50,2
78	418	640	412	611	293	252	289	244	217	115	214	111	169	61	168	58,3	163	54,2	161	52,8
80	429	673	422	646	300	265	297	256	222	121	220	117	174	63,2	172	61,5	167	57	165	55,6
85	455	759	449	729	319	299	315	290	236	136	233	132	184	71,3	183	69,3	177	64,4	176	62,9
90	482	851	475	813	338	336	334	325	250	153	247	148	195	79,9	193	77,9	188	72,1	186	70,3
95	509	949	501	911	357	374	352	362	264	170	261	165	206	89,1	204	86,8	198	80,4	197	78,4
100	536	1051	528	1009	376	415	371	401	278	188	275	183	217	98,7	215	96,2	209	89,1	207	86,8
105	563	1159	554	1113	394	457	389	442	292	208	288	202	228	109	225	106	219	98,2	217	95,7
110	590	1271	580	1221	413	502	408	485	306	228	302	221	239	119	236	116	229	108	227	105
115					432	548	426	530	319	249	316	242	249	131	247	127	240	118	238	115
120					451	597	445	577	333	271	330	264	261	142	258	138	250	128	248	125
125					470	648	463	625	347	294	343	286	271	154	268	150	261	139	258	135
130					488	701	481	677	361	318	357	309	282	167	279	163	271	151	269	147
135					507	755	501	730	375	343	371	333	293	180	290	175	282	162	279	159
140					526	813	519	745	389	369	385	358	304	194	301	188	292	175	289	170
145					545	872	538	843	403	396	398	385	314	207	311	202	302	187	299	183
150					563	933	556	902	417	424	412	412	325	222	322	216	313	200	310	195
155					582	996	575	963	431	452	426	439	336	237	333	231	323	214	320	209

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Continuation Table 9.19.

$D_н \times s$ мм ④	478×7		478×6		529×7		529×6		630×8		630×7		720×9		720×8		720×7		820×9		820×8	
G ② кг/с	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²
52	85,5	13	84,8	12,7	69,4	7,5	68,9	7,4	48,8	3,1	48,5	3										
54	88,8	14	88	13,7	72,1	8,1	71,5	7,9	50,7	3,3	50,4	3,2										
56	92	15,1	91,3	14,7	74,7	8,7	74,2	8,5	52,6	3,5	52,2	3,5										
58	95,4	16,1	95	15,7	77,4	9,3	76,8	9,2	54,5	3,7	54,1	3,7										
60	98,7	17,2	97,8	16,9	80,1	10	79,5	9,8	56,3	4	56	3,9										
62	102	18,4	101	18	82,8	10,7	82,1	10,5	58,2	4,3	57,8	4,2	44,5	2,2	44,3	2,1	44	2,1	34,1	1,1	34	1,06
64	105	19,6	104	19,2	85,4	11,4	84,8	11,2	60	4,5	59,7	4,5	46	2,4	45,7	2,3	45,5	2,2	35,2	1,25	35	1,15
66	109	20,9	108	20,4	88,1	12,1	87,4	11,9	62	4,8	61,6	4,8	47,4	2,5	47,1	2,4	46,9	2,3	36,3	1,3	36,1	1,21
68	112	22,1	111	21,6	90,8	12,8	90,1	12,6	63,9	5,1	63,4	5	48,8	2,6	48,6	2,5	48,3	2,5	37,4	1,33	37,2	1,3
70	115	23,5	114	22,9	93,4	13,6	92,7	13,3	65,7	5,4	65,3	5,3	50,3	2,8	50	2,7	49,7	2,6	38,5	1,4	38,3	1,35
72	118	24,8	117	24,3	96,1	14,4	95,4	14,1	67,6	5,8	67,2	5,7	51,7	2,9	51,4	2,8	51,1	2,8	39,6	1,48	39,4	1,4
74	121	26,2	121	25,6	98,8	15,2	98	14,9	69,5	6,1	69	6	53,2	3	52,9	3	52,6	3	40,7	1,57	40,5	1,5
76	125	27,7	124	27	101	16	101	15,7	71,4	6,4	70,9	6,3	54,6	3,2	54,3	3,1	54	3,1	41,8	1,63	41,6	1,61
78	128	29,1	127	28,5	104	16,9	103	16,6	73,2	6,8	72,8	6,6	56	3,4	55,7	3,3	55,4	3,2	42,9	1,71	42,7	1,68
80	132	30,6	130	30	108	17,8	106	17,4	75,1	7,1	74,6	7	57,5	3,5	57,1	3,5	56,8	3,4	44	1,8	43,8	1,76
85	140	34,6	139	33,8	114	20,1	113	19,7	79,8	8	79,3	7,9	61,1	4	60,7	4	60,4	3,8	46,8	2	46,6	1,9
90	148	38,8	147	37,9	120	22,5	119	22,1	84,5	9	84	8,8	64,7	4,5	64,3	4,4	63,9	4,3	49,5	2,2	49,3	2,12
95	156	43,2	155	42,3	127	25,1	126	24,6	89,2	10	88,7	9,8	68,3	5	67,9	4,9	67,5	4,8	52,3	2,5	52,1	2,4
100	164	47,9	163	46,8	133	27,8	132	27,2	93,9	11,1	93,3	10,9	71,8	5,5	71,4	5,4	71	5,4	55	2,8	54,8	2,7
105	173	52,8	171	51,6	140	30,7	139	30	98,5	12,3	98,2	12	75,4	6,1	75	6	74,6	6	57,8	3	57,5	3
110	181	57,9	179	56,7	147	33,6	146	32,9	103	13,4	103	13,2	79	6,7	78,6	6,6	78,1	6,5	60,5	3,3	60,2	3,3
115	189	63,3	187	61,9	153	36,7	152	36	108	14,7	107	14,4	82,6	7,3	82,1	7,2	81,6	7,1	63,3	3,7	63	3,6
120	197	69	196	67,1	160	40	159	39,2	113	16	112	15,7	87,2	8	85,7	7,8	85,2	7,7	66	4	65,7	3,9
125	206	74,8	204	73,2	167	43,4	166	42,5	117	17,3	117	17,1	89,8	8,6	89,3	8,5	88,8	8,4	68,8	4,3	68,5	4,3
130	214	80,9	212	79,1	174	47	172	46	122	18,8	121	18,5	93,4	9,3	92,9	9,2	92,3	9,1	71,5	4,7	71,2	4,6
135	222	87,3	220	85,3	180	50,6	179	49,6	127	20,2	126	19,9	97	10,1	96,4	9,9	95,9	9,8	74,3	5	73,9	5
140	230	93,8	228	91,8	187	54,5	185	53,4	131	21,8	131	21,4	101	10,8	100	10,7	99,4	10,5	77,1	5,4	76,7	5,3
145	238	101	236	98,4	194	58,4	192	57,2	136	23,3	135	23	104	11,6	104	11,4	103	11,3	79,8	5,8	79,4	5,7
150	247	108	245	105	200	62,5	199	61,3	141	25	140	24,6	108	12,4	107	12,2	107	12,1	82,6	6,2	82,1	6,1
155	255	115	253	112	207	66,8	205	65,4	146	26,7	145	26,2	111	13,3	111	13,1	110	12,9	85,3	6,6	84,9	6,5

Continuation Table 9.19.

$D_н \times s$ мм ④	377×10		377×9		426×11		426×10		426×7		426×6		478×7		478×6		529×7		529×6		630×8	
G ② кг/с	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²	③ v м/с	④ Δh кгс/м²
160	444	482	439	468	347	273	344	266	334	258	330	252	263	123	261	120	214	71,1	212	69,7	150	28,4
165	458	513	453	498	358	289	354	282	344	273	341	267	271	130	269	127	220	75,6	219	74,1	155	30,2
170	472	544	467	529	369	305	365	298	355	289	351	283	280	138	277	135	227	80,3	225	78,7	160	32,1
175	486	577	481	560	380	322	376	315	365	305	361	298	288	147	285	143	234	85,1	232	83,4	164	34
180	500	610	494	593	390	340	387	332	375	322	372	315	296	155	293	152	240	90	238	88,2	169	36
190	528	680	522	660	412	376	408	368	396	356	392	348	312	173	310	169	254	100	252	98,3	178	40,1
200	556	753	549	732	434	395	430	385	417	374	413	367	328	192	326	187	267	111	265	109	188	44,4
210	583	831	577	807	455	435	451	424	438	393	434	383	345	211	342	206	280	123	278	120	197	49
220	611	912	604	885	477	478	472	465	459	431	454	420	362	232	359	227	294	134	291	132	207	53,7
230	639	996	632	968	499	522	494	509	480	471	475	459	378	253	375	248	307	147	305	144	216	58,7
240	667	1085	659	1054	521	568	515	554	501	513	496	500	395	276	391	270	320	160	318	157	225	64
250	694	1177	687	1143	542	617	537	601	521	557	516	543	411	299	408	293	334	174	331	170	235	69,4
260	722	1273	714	1235	564	667	558	650	542	602	537	587	428	324	424	316	347	188	344	184	244	75,1
270	750	1373	742	1333	586	719	580	701	563	649	558	633	444	3 9	440	341	360	203	358	198	254	80,9
280	778	1477	769	1434	607	774	601	754	584	698	578	681	460	375	456	367	374	218	371	213	263	87,1
290	805	1584	797	1538	629	830	623	809	605	749	599	730	477	403	473	394	387	234	384	229	272	93,4
300	833	1695	824	1646	651	888	644	865	626	802	620	782	493	431	489	421	400	250	397	245	282	99,9
310					672	948	666	924	647	856	640	835	510	460	505	450	414	267	411	262	291	107
320					694	1010	687	985	667	912	661	890	526	490	522	479	427	285	424	279	300	114
330					716	1074	709	1047	688	970	682	946	543	521	538	510	440	303	437	297	310	121
340					737	1141	730	1112	709	1030	702	1004	559	554	554	541	454	321	450	315	319	128
350					759	1209	752	1178	730	1091	723	1064	575	587	571	574	467	340	464	334	329	136
360					781	1279	773	1246	751	1154	744	1126	592	621	587	607	480	360	477	353	338	144
370					802	1351	795	1317	772	1219	764	1189	608	656	603	641	494	380	490	373	347	152
380					824	1424	816	1389	792	1286	785	1254	625	691	619	676	507	401	503	393	357	160
390							838	1463	813	1354	806	1320	641	728	636	712	521	423	517	414	366	169
400													658	766	652	749	539	445	530	436	376	178
410													674	805	668	787	547	467	543	458	385	187
420													691	845	685	826	561	490	556	480	394	196
430													707	885	701	866	574	514	569	503	404	205

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Continuation Table 9.19.

$D_H \times s$ мм (1)	630×7		720×9		720×8		720×7		820×9		820×8		920×10		920×9		920×8		1020×11		1020×10		1020×8	
G кг/с (2)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)
160	149	27,9	115	14,1	114	13,9	114	13,7	98,1	7,1	87,6	7	69,9	3,9	69,6	3,8	69,3	3,8	55,9	2,3	56,5	2,2	56,1	2,2
165	154	29,7	119	15	118	14,8	117	14,6	101,3	7,5	90,4	7,4	72,1	4,1	71,8	4,1	71,5	4	58,6	2,4	58,3	2,4	57,9	2,3
170	159	31,6	122	16	121	15,7	121	15,5	93,6	8	93,1	7,9	74,3	4,4	74	4,3	73,6	4,3	60,4	2,6	60,1	2,5	59,7	2,5
175	163	33,4	126	16,9	125	16,7	124	16,4	95,3	8,5	95,8	8,3	76,5	4,6	76,1	4,6	75,8	4,5	62,2	2,7	62	2,7	61,5	2,6
180	168	35,4	129	17,9	129	17,6	128	17,4	99,1	8,9	98,6	8,5	78,7	4,9	78,3	4,9	78	4,8	64	2,9	63,7	2,8	63,2	2,8
190	173	37,4	135	19,9	136	19,6	135	19,4	105	10	104	9,8	83	5,5	82,7	5,4	82,3	5,3	67,5	3,2	67,3	3,2	66,7	3,1
200	187	43,7	144	22,1	139	20,7	142	21,5	110	11	110	10,9	87,4	6,1	87	6	86,6	5,9	71,1	3,5	70,8	3,5	70,2	3,4
210	196	48,1	151	24,4	150	24	149	23,7	116	12,2	115	12	91,8	6,7	91,4	6,6	91	6,5	74,6	3,9	74,3	3,9	73,7	3,8
220	205	52,8	158	26,7	157	26,3	156	26	121	13,1	120	13,2	96,1	7,3	95,7	7,2	95,3	7,2	78,2	4,3	77,9	4,2	77,3	4,1
230	215	57,8	165	29,2	164	28,8	163	28,4	127	14,6	125	14,4	101	8	100	7,9	99,6	7,8	81,7	4,7	81,4	4,6	80,8	4,5
240	224	62,9	172	31,8	171	31,4	170	30,9	132	15,9	131	15,7	105	8,7	104	8,6	104	8,5	85,3	5,1	85	5	84,3	4,9
250	233	68,2	180	34,5	179	34	178	33,5	138	17,3	137	17	109	9,5	109	9,4	108	9,2	88,9	5,5	88,5	5,5	87,8	5,4
260	243	73,8	187	37,3	186	36,8	185	36,3	143	18,7	142	18,4	114	10,2	113	10,1	113	10	92,4	6	92	5,9	91,3	5,8
270	252	79,6	194	40,3	193	39,7	192	39,1	149	20,1	148	19,9	118	11	117	10,9	117	10,8	96	6,4	95,6	6,4	94,8	6,2
280	261	85,6	201	43,3	200	42,7	199	42	154	21,6	153	21,4	122	11,9	120	11,8	121	11,6	99,5	6,9	99,1	6,9	98,3	6,7
290	271	91,8	208	46,5	207	45,8	205	45,1	160	23,2	159	22,9	127	12,7	126	12,6	126	12,4	103	7,4	103	7,4	102	7,2
300	280	98,3	216	49,7	214	49	213	48,3	165	24,8	164	24,5	131	13,6	131	13,5	130	13,3	107	8	106	7,9	105	7,7
310	289	105	223	53,1	221	52,3	220	51,5	171	26,5	170	26,2	135	14,6	135	14,4	134	14,2	110	8,5	110	8,4	109	8,2
320	299	112	230	56,6	229	55,7	227	54,5	176	28,3	175	27,9	140	15,5	139	15,3	139	15,2	114	9,1	113	9	112	8,8
330	308	119	237	60,2	235	59,3	234	58,9	182	30,1	181	29,7	144	16,5	144	16,3	143	16,1	117	9,6	117	9,5	116	9,3
340	317	126	244	63,9	243	62,9	241	62	187	31,9	186	31,5	149	17,5	148	17,3	147	17,1	121	10,2	120	10,1	119	9,9
350	327	134	251	67,7	250	66,7	249	65,7	193	33,8	192	33,4	153	18,6	152	18,3	152	18,1	124	10,5	124	10,4	123	10,3
360	336	141	259	71,6	257	70,5	256	69,5	198	35,8	197	35,3	157	19,6	157	19,4	156	19,2	128	11,5	127	11,3	126	11,1
370	345	149	266	75,6	264	74,5	263	73,4	204	37,8	203	37,3	162	20,7	161	20,5	160	20,3	132	12,1	131	12	130	11,7
380	355	158	273	79,8	271	78,6	270	77,4	209	39,9	208	39,3	166	21,9	165	21,6	165	21,4	135	12,8	135	12,6	133	12,4
390	364	166	280	84	279	82,8	277	81,6	215	42	214	41,4	170	23	170	22,8	169	22,5	139	13,5	138	13,3	137	13
400	373	175	287	88,4	286	87,1	284	85,8	220	44,2	219	43,6	175	24,2	174	24,0	173	23,7	142	14,2	142	14	140	13,7
410	383	184	295	93,4	293	91,5	291	90,3	226	46,5	225	45,8	180	25,4	179	25,2	178	24,9	146	14,9	146	14,7	144	14,4
420	392	193	302	97,4	300	96	298	94,6	231	48,7	230	48,1	184	25,7	183	26,4	182	26,1	149	15,6	149	15,4	147	15,1
430	401	202	309	102	307	101	305	99,1	237	51	236	50,4	188	28	187	27,7	187	27,4	153	16,4	153	16,1	156	15,8

Continuation Table 9.19.

$D_H \times s$ мм (1)	529×7		529×6		630×8		630×7		720×9		720×8		720×7		820×9
G кг/с (2)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)	Δh кгс/м² (4)	v м/с (3)
440	587	538	583	527	413	215	410	211	316	107	314	105	312	104	242
450	601	563	596	551	423	225	420	221	323	112	322	110	320	109	248
460	614	588	609	576	432	235	429	231	330	117	329	115	327	113	253
470	627	614	622	601	442	246	439	242	338	122	336	120	334	118	259
480	641	640	636	627	451	256	448	252	345	127	343	125	341	124	264
490	654	567	649	654	461	264	457	263	352	133	350	131	348	129	270
500	667	695	662	681	470	278	465	273	359	138	357	136	355	134	275
520	694	751	689	736	488	300	485	295	374	149	371	147	369	145	286
540	721	810	715	794	507	324	504	318	388	161	385	159	384	156	297
560	747	871	742	854	526	348	522	342	402	173	400	171	398	168	308
580	774	935	768	916	545	374	541	367	417	186	414	183	412	180	319
600	801	1000	795	980	563	400	560	393	431	199	429	195	426	193	330
620	828	1068	821	1047	582	427	578	420	445	212	443	209	440	206	341
640	854	1138	848	1115	601	455	597	447	460	226	457	223	455	220	352
660					620	484	616	476	474	241	471	237	469	234	363
680					639	513	634	505	488	255	486	252	483	248	374
700					657	544	653	535	503	271	500	267	497	263	385
720					676	576	672	566	517	286	514	282	511	278	396
740					695	608	690	598	532	303	529	298	525	294	407
760					714	641	709	631	546	319	543	314	540	310	418
780					732	676	728	654	560	336	557	331	554	326	429
800					751	711	746	699	575	354	571	348	568	343	440
820					770	747	765	734	589	371	586	365	582	361	451
840					789	783	784	770	603	390	600	384	597	378	462
860					808	821	802	807	618	409	614	403	611	397	473
880					826	860	821	845	632	428	629	421	625	415	484
900					845	899	840	884	647	447	643	441	639	434	495
920					864	940	858	924	661	468	657	461	653	454	506
940					883	981	877	965	675	488	671	481	668	474	517
960					901	1023	896	1006	695	509	688	502	682	494	528

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Continuation Table 9.19.

$D_н \times s$ мм (1)	820×9	820×8		920×10		920×9		920×8		1020×11		1020×10		1020×8	
(2) G в т/ч	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²
440	53,4	241	52,8	192	29,3	191	29	191	28,7	156	17,1	156	16,9	155	16,6
450	55,9	247	55,3	197	30,6	196	30,3	195	30	160	17,9	160	17,7	159	17,4
460	58,4	252	57,7	201	32	200	31,7	199	31,3	163	18,7	163	18,5	162	18,1
470	61	258	60,2	206	33,4	205	33,1	204	32,6	167	19,5	167	19,3	166	18,9
480	63,6	263	62,8	210	34,9	209	34,5	208	34,1	171	20,4	170	20,2	169	19,8
490	66,3	269	65,5	215	36,4	214	36	213	35,5	175	21,2	174	21	173	20,6
500	69	274	68,1	219	37,9	218	37,4	217	37	178	22,1	177	21,9	176	21,4
520	74,6	285	73,7	227	41	226	40,5	225	40	185	23,9	184	23,7	183	23,2
540	80,5	296	79,5	236	44,2	235	43,7	234	43,2	192	25,8	191	25,5	190	25
560	86,6	307	85,4	245	47,5	244	46,9	243	46,4	199	27,7	198	27,4	197	26,9
580	92,9	318	91,7	253	50,9	252	50,4	251	49,8	206	29,8	205	29,4	204	28,8
600	99,4	329	98,1	262	54,5	261	53,9	260	53,3	213	31,8	212	31,3	211	30,9
620	106	340	105	271	58,2	270	57,5	269	56,9	220	34	219	33,6	218	33
640	113	350	112	280	62	278	61,3	277	60,6	227	36,2	227	35,8	225	35,1
660	120	361	119	288	66	287	65,2	286	64,5	235	38,5	234	38,1	232	37,3
680	128	372	126	297	70	296	69,2	295	68,4	242	40,9	241	40,5	239	39,6
700	135	383	134	306	74,2	305	73,4	303	72,5	249	43,3	248	42,9	246	42
720	143	394	141	315	78,5	313	77,6	312	76,7	256	45,8	255	45,4	253	44,4
740	151	405	149	323	82,9	322	82	321	81	263	48,4	262	47,9	260	46,9
760	159	416	157	332	87,5	331	86,5	329	85,5	270	51,1	269	50,6	267	49,5
780	168	427	166	341	92,1	339	91,1	338	90	277	53,8	276	53,2	274	52,2
800	177	438	174	350	97	348	95,8	347	94,7	284	56,6	283	56	281	54,9
820	186	449	183	358	102	357	101	355	99,5	291	59,5	290	58,8	288	57,6
840	19,5	460	192	367	107	365	106	364	104	299	62,4	297	61,8	295	60,5
860	204	471	202	376	112	374	111	373	109	306	65,4	304	64,7	302	63,4
880	214	482	211	385	117	383	116	381	115	313	68,5	312	67,8	309	66,4
900	224	493	221	393	123	392	121	390	120	320	71,6	319	70,9	316	69,4
920	234	504	231	402	128	400	127	399	125	327	74,9	326	74,1	323	72,6
940	244	515	241	411	134	409	132	407	131	334	78,1	333	77,3	330	75,7
960	254	526	251	420	140	418	138	416	136	341	81,5	340	80,7	337	79

Continuation Table 9.19.

$D_н \times s$ мм (1)	720×9		720×8		720×7		820×9		820×8		920×10		920×9		920×8		1020×11		1020×10		1020×8	
(2) G в т/ч	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²	(3) υ в м/сек	(4) Δh в кгс/м²
980	704	531	700	523	696	515	539	265	537	262	428	145	426	144	425	142	348	84,9	347	84,1	344	82,3
1000	718	552	714	544	710	536	550	276	548	272	437	151	435	150	433	148	355	88,4	354	87,5	351	85,7
1020	733	575	729	566	724	558	561	287	559	283	446	157	444	156	441	154	362	92	361	91	358	89,2
1040	747	597	743	589	739	581	572	299	570	295	455	163	453	162	451	160	370	95,6	369	94,6	365	92,9
1060	761	621	757	612	754	603	583	310	580	306	463	170	461	169	459	166	376	99,5	375	98,4	372	96,3
1080	776	644	771	635	767	626	594	322	591	318	472	176	470	175	468	173	384	103	383	102	380	100
1100	790	668	786	659	781	649	605	334	602	330	481	183	479	181	476	179	391	107	389	106	386	104
1150	826	731	821	720	817	709	633	365	630	360	503	200	501	198	498	196	409	117	407	116	404	113
1200	862	795	857	784	852	772	660	397	657	392	524	218	522	216	520	213	427	127	425	126	421	123
1250	898	863	893	850	888	838	688	431	685	425	546	237	544	234	541	231	444	138	443	137	439	134
1300	934	934	929	920	923	906	715	466	712	460	568	256	566	253	563	250	462	149	460	148	457	145
1350	970	1006	964	992	959	977	743	503	739	497	590	276	587	273	585	270	480	161	478	160	474	156
1400	1010	1083	1000	1067	994	1051	771	541	767	534	612	297	609	293	606	290	498	173	496	172	492	168
1450							798	580	794	573	634	318	631	315	628	311	515	186	513	184	509	180
1500							826	621	821	613	656	341	653	337	650	333	533	199	531	197	527	193
1550							853	663	849	655	677	364	674	360	671	356	551	212	549	210	544	206
1600							881	707	876	698	699	388	696	383	693	379	569	226	566	224	562	219
1650							908	752	904	742	721	412	718	408	715	403	585	241	584	238	579	233
1700							936	798	931	787	743	438	740	433	736	428	604	256	602	253	597	248
1750							963	845	958	834	765	464	761	458	758	453	622	271	620	268	615	263
1800							991	894	985	883	787	491	783	485	780	479	640	287	637	284	632	278
1850							1018	945	1013	933	809	518	805	512	801	507	658	303	655	300	650	293
1900							1046	996	1041	984	830	547	827	540	823	534	675	319	673	316	667	309
1950							1073	1050	1068	1036	852	576	848	569	845	563	693	336	690	333	685	326
2000							1101	1104	1095	1090	874	606	870	599	866	592	711	354	708	350	702	343
2100											918	668	914	660	910	653	746	390	743	386	737	378
2200											961	733	957	725	953	716	782	428	779	424	773	415
2300											1005	801	1001	792	996	783	817	468	814	463	808	453
2400											1049	872	1044	862	1040	852	853	509	850	504	843	494
2500											1093	947	1088	936	1083	925	889	553	885	547	878	536

Note to table 9.19 and 9.24. Greasy/fatty of lines is designated the boundary/interface between the transfer and quadratic range.

Key: (1). in mm. (2). in t/h. (3). in m/s. (4). in kgf/m² m.

Pages 144-147.

Table 9.20. Equivalent lengths of the local resistances at $k_э = 0{,}2$ mm for tubes $D_y = 25 \div 400$ mm.

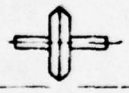
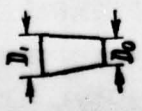
Наименование местных сопротивлений (1)	Эскизы (2)	(3) Эквивалентные длины местных сопротивлений $l_э$									
		32	33,5	38	42,3	44,5	45	48	57	60	75,5
Задвижка (4)		–	–	–	–	–	–	–	0,88	0,97	1,33
Вентиль: (4а)		7,1	7,5	8,2	9,4	10,4	10,8	10,9	11,4	11,7	12
(5) с вертикальным шпинделем											
(6), косым		0,79	0,75	0,87	0,94	0,98	1,02	1,02	1,23	1,26	1,73
Обратный клапан: (7)											
поворотный („заслонка") (8)		1,03	1,08	1,33	1,52	1,69	1,7	1,82	2,29	2,72	3,72
подъемный (9)		5,3	5,8	7,1	8,2	9,1	9,2	9,8	12,3	13,6	18,6
Сальниковый компенсатор: (10)											
односторонний (11)		–	–	–	–	–	–	–	–	–	–
двусторонний (12)		–	–	–	–	–	–	–	–	–	–
Грязевик промывочный (13)		–	–	–	–	–	–	–	–	–	–
Отводы сварные одношовные с углом: (14)											
30°		–	–	–	–	–	–	–	–	–	–
45°		–	–	–	–	–	–	–	–	–	
60°		–	–	–	–	–	–	–	–	–	–
90°		–	–	–	–	–	–	–	–	–	–
Отводы сварные под углом 90°: (15)											
(16) двухшовные, $R = 1D$		–	–	–	–	–	–	–	–	–	–
(17) трехшовные, $R = 1{,}5D$		–	–	–	–	–	–	–	–	–	–
(18) четырехшовные, $R = 1D$		–	–	–	–	–	–	–	–	–	–

Continuation Table 9.20.

при наружных диаметрах труб в мм

76	88.5	89	101,3	108	114	133	140	152	159	165	194	219	273	325	377	426
1,33	1,65	1,67	1,97	2,12	2,3	2,32	2,4	2,68	2,76	3,02	3,63	4,2	4,2	5,2	6,3	7,36
12,5	13,2	13,3	15,7	17,4	18,9	23,8	25,2	28,8	30,4	34	42	49,3	—	—	—	—
1,73	1,98	2	2,07	2,12	—	—	—	—	—	—	—	—	—	—	—	—
3,72 18,6	4,6 23,1	4,64 23,3	5,9 27,5	6,36 29,7	6,86 32	9,05 39,8	9,6 42	11,4 47	11,7 48,3	12,9 53	16,5 64	20 73,5	28 —	36,5 —	46 —	57,2 —
—	—	—	—	0,85	0,92	1,13	1,8	2,01	2,07	2,26	2,74	3,15	4,2	5,2	6,3	12,5
—	—	—	—	2,55	2,75	3,4	3,6	4,02	4,14	4,53	5,5	6,3	8,4	10,4	12,6	15
—	—	—	—	—	—	—	—	67	69	75,5	91,5	105	140	174	209	249
—	—	—	—	—	—	—	—	1,34	1,38	1,51	1,83	2,1	2,8	3,48	4,2	5
—	—	—	—	—	—	—	—	2,01	2,07	2,26	2,74	3,15	4,2	5,2	6,3	7,46
—	—	—	—	—	—	—	—	4,7	4,83	5,3	6,4	7,35	9,8	12,2	14,6	17,5
—	—	—	—	—	—	—	—	8,7	9	9,8	11,9	13,7	18,2	22,6	27,2	32,4
—	—	—	—	—	—	—	—	4,7	4,83	5,3	6,4	7,35	9,8	12,2	14,6	17,5
—	—	—	—	—	—	—	—	4,02	4,14	4,53	5,5	6,3	8,4	10,4	12,6	15
—	—	—	—	—	—	—	—	4,02	4,14	4,53	5,5	6,3	8,4	10,4	12,6	15

Continuation Table 9.20.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений $l_э$									
		32	33,5	38	42,3	44,5	45	48	57	60	75,5
(19) Отводы крутоизогнутые, $R = 1,5D \div 2D$		0,4	0,42	0,51	0,59	0,65	0,66	0,7	0,88	0,97	1,33
(20) Отводы гнутые гладкие:											
$R = 3D$		0,32	0,33	0,41	0,47	0,52	0,52	0,56	0,7	0,78	1,06
$R > 4D$		0,24	0,25	0,31	0,35	0,39	0,39	0,42	0,53	0,58	0,8
(21) Компенсаторы П-образные со сварными трехшовными отводами, $R = 1,5D$		–	–	–	–	–	–	–	–	–	–
(22) Компенсаторы П-образные с крутоизогнутыми отводами:											
$R = 1,5D$		5,1	5,2	5,6	6	6,5	6,6	6,7	8,1	8,5	10,5
$R = 2D$											
(23) Компенсаторы П-образные с гнутыми гладкими отводами:											
$R = 3D$		3,9	3,9	4,2	4,5	4,7	4,7	4,8	6	6,3	7,9
$R > 4D$		3,4	3,4	3,6	3,8	3,9	3,9	4	4,9	5,1	6
(24) Компенсатор однолинзовый:											
(25) без рубашки[a]		–	–	–	–	–	–	–	–	–	
(26) с рубашкой		–	–	–	–	–	–	–	–	–	–
(27) Тройник при разделении потока:											
(28) проход[a]		0,79	0,83	1,02	1,17	1,3	1,31	1,4	1,76	1,94	2,66
(29) ответвление		1,19	1,25	1,53	1,75	1,95	1,97	2,1	2,64	2,91	4
(30) Тройник при слиянии потока:											
(28) проход[a]		1,19	1,25	1,53	1,75	1,95	1,97	2,1	2,64	2,91	4
(29) ответвление		1,58	1,66	2,04	2,34	2,6	2,62	2,8	3,52	3,88	5,32
(31) Тройники:											
(32) при расходящемся потоке		1,58	,66	2,04	2,34	2,6	2,62	2,8	3,52	3,88	5,32
(33) встречном		2,37	2,49	3,06	3,51	3,9	3,93	4,2	5,28	5,82	8
(34) Переходы сварные (по МН 2883–62)[a]:											
$F_1/F_0 = 2$		–	–	–	0,12	0,13	0,13	0,14	0,18	0,19	0,27
$F_1/F_0 =$		–	–	–	0,18	0,2	0,2	0,21	0,26	0,29	0,4
$F_1/F_0 = 4$		–	–	–	0,23	0,26	0,26	0,28	0,35	0,39	0,53

Continuation Table 9.20.

при наружных диаметрах труб в *мм*

76	88,5	89	101,3	108	114	133	140	152	159	165	194	219	273	325	377	426
1,33	1,65	1,67	1,97	2,12	2,3	2,82	3	3,35	3,45	3,78	4,6	5,25	7	8,7	10,5	12,5
1,06	1,3	1,33	1,57	1,7	1,83	2,26	2,4	2,68	2,76	3,02	3,66	4,2	5,6	6,95	8,4	9,95
0,8	0,99	1	1,18	1,27	1,37	1,7	1,8	2,01	2,07	2,26	2,74	3,15	4,2	5,2	6,3	7,46
—	—	—	—	—	—	—	—	23,5	24	25,5	30,8	34,6	44,6	53,2	63,4	74,2
10,5	12,8	12,9	14,1	14,9	15,6	19,4	19,5	20,8	21,2	22,5	27,2	30,4	40	46,2	55	64,2
7,9	9,3	9,4	10,4	10,8	11,3	13,2	13,8	15,3	15,6	16,7	20	22	28	33	39	45,2
6	7,4	7,4	8,1	8,3	8,7	10	10,4	11,4	11,7	12,4	15	16,2	20,4	24	28	32
—	—	—	—	7,2	7,8	9,6	10,2	10,3	10,4	11,3	12,8	13,7	16,8	17,4	1 8	19,9
—	—	—	—	0,42	0,46	0,56	0,6	0,67	0,69	0,76	0,92	1,05	1,4	1,74	2,09	2,49
2,66	3,3	3,33	3,93	4,24	4,57	5,65	6	6,7	6,9	7,55	9,15	10,5	14	17,4	20,9	24,9
4	4,95	5	5,9	6,36	6,86	8,5	9	10	10,4	11,3	13,7	15,8	21	26,	31,4	37,3
4	4,95	5	5,9	6,36	6,86	8,5	9	10	10,4	11,3	13,7	15,8	21	26,1	31,4	37,3
5,32	6,6	6,66	7,86	8,5	9,15	11,3	12	13,4	13,8	15,1	18,3	21	28	34,8	41,8	49,8
5,32	6,6	6,66	7,86	8,5	9,15	11,3	12	13,4	13,8	15,1	18,3	21	28	34,8	41,8	49,8
8	9,9	10	11,8	12,7	13,7	17	18	20,1	20,7	22,6	27,4	31,5	42	52	62,7	74,6
0,27	0,33	0,33	0,39	0,42	0,46	0,56	0,6	0,67	0,69	0,76	0,92	1,05	1 4	1,74	2,09	2,49
0,4	0,5	0,5	1,18	1,27	1,37	1,7	1,8	2,01	2,07	2,26	2,74	3,15	4,2	5,2	6,3	7,46
0,53	0,66	0,67	1,97	2,12	2,3	2,82	3	3,35	3,45	3,78	4,6	5,25	7	8,7	10,5	12,5

Note. See footnotes to Table 9.12.

Key: (1). Designation of local resistance. (2). Draft/drawings. (3). Equivalent lengths of local resistance with the outside diameters of tubes in mm. (4). Catch [1]. (4a). Valve/gate. (5). with vertical shaft. (6). with oblique. (7). Check valve. (8). rotary ("flap"). (9). lift. (10). Gasket compensator. (11). one-way. (12). bilateral. (13). Sludge pan is washing. (14). Branch/removals welded single-seam with angle. (15). Branch/removals are welded at an angle of 90°. (16). two-seam, R = 1 D. (17). three-seam, R = 1.5 D. (18). Four-seam, R = 1 D. (19). Branch/removals sharply bent, R = 1.5 D-2 D. (20). Branch/removals the bent smooth. (21). Compensators U-shaped with welded three-seam branch/removals, R = 1.5 D. (22). Compensators are U-shaped with sharply bent branch/removals. (23). Compensators are U-shaped with the bent smooth branch/removals. (24). Compensator is single-lens. (25). without jacket[2]. (26). with jacket. (27). -piece during the separation of flow. (28). pass [3]. (29). branch. (30). -piece with the merging/coalescence of flow. (31). -pieces. (32). with the diverging flow. (33). contrary. (34). Transfer/transitions welded (on MN 2883-62) [4].

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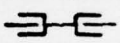
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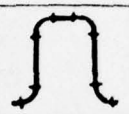
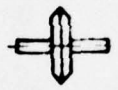
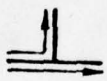
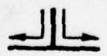
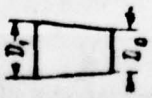


Pages 148 and 149.

Table 9.21. Equivalent lengths of local resistance with $k_э$=0.2 мм for tubes D_y=450 ÷ 1200 мм.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений $l_э$ при наружных диаметрах труб в мм							
		478	529	630	720	820	920	1020	1220
(4) Задвижка[1]		5,8	6,5	6,9	7,4	7,8	8,3	8,7	9,2
(5) Обратный клапан поворотный („захлопка")		69,6	81,7	110	138,5	162	194	219	274,5
(6) Сальниковый компенсатор: (7) односторонний		14,5	16,4	20,3	23,9	28	32,3	36,5	45,6
(8) двусторонний		17,4	19,6	24,4	28,6	33,5	38,7	43,8	54,9
(9) Грязевик промывочный		290	327	406	477	558	645	730	915
(10) Отводы сварные одношовные с углом: 30°		5,8	6,5	8,1	9,5	11,2	12,9	14,6	18,3
45°		8,7	9,8	12,2	14,3	16,8	19,4	21,9	27,4
60°		20,3	22,9	28,4	33,4	39,1	45,2	51,1	64
90°		37,7	42,5	52,7	62	72,5	83,8	95	119
(11) Отводы сварные с углом 90°: (12) двухшовные, $R = 1D$		20,3	22,9	28,4	33,4	39,1	45,2	51,1	64
(13) трехшовные, $R = 1D$		20,3	22,9	28,4	33,4	39,1	45,2	51,1	64
(14) трехшовные, $R = 1,5D$		17,4	19,6	24,4	28,6	33,5	38,7	43,8	54,9

Continuation Table 9.21.

(1) Наименование местных сопротивлений	(2) Эскизы	(3) Эквивалентные длины местных сопротивлений l, при наружных диаметрах труб в мм							
		478	529	630	720	820	920	1020	1220
(14) четырехшовные, $R = 1D$		17,4	19,6	24,4	28,6	33,5	38,7	43,8	54,9
(15) Отводы крутоизогнутые $R = 1D$; $R = 1,5D$		14,5	16,4	20,3	23,9	28	32,3	36,5	45,6
(16) Компенсаторы П-образные со сварными трехшовными отводами:									
$R = 1D$		105	119	142	164	209	214	238	290
$R = 1,5D$		92	103	124	142	162	184	205	250
(17) Компенсаторы П-образные с крутоизогнутыми отводами $R = 1D$; $R = 1,5D$		86	93	110	126	144	162	180	216
(18) Компенсатор однолинзовый:									
(19) без рубашки[2]		20,3	21,2	24,4	27,7	30,2	32,3	36,5	45,6
(20) с рубашкой		2,9	3,3	4,1	4,8	5,6	6,5	7,3	9,2
(21) Тройник при разделении потока:									
(22) проход[3]		29	32,7	40,6	47,7	55,8	64,5	73	91,5
(23) ответвление		43,5	49	60,9	71,6	83,7	96,7	109,5	137
(24) Тройник при слиянии потока:									
(22) проход[3]		43,5	49	60,9	71,6	83,7	96,7	110	137
(23) ответвление		58	65,4	81	95,5	112	129	146	183
(25) Тройники:									
(26) при расходящемся потоке		58	65,4	81	95,5	112	129	146	183
(27) встречном		87	98	122	143	168	194	219	274
(28) Переходы сварные (МН 2883–62):[4]									
$F_1/F_0 = 2$		2,9	3,3	4,1	4,8	5,6	6,5	7,3	9,2
$F_1/F_0 = 3$		5,8	6,5	8,1	9,5	11,2	12,9	14,6	18,3
$F_1/F_0 = 4$		8,7	9,8	12,2	14,3	16,8	19,4	21,9	27,4

Note. See footnotes to Table 9.12.

Key: (1). Designation of local resistance. (2). Draft/drawings. (3). Equivalent lengths of local resistance with the outside diameters of tubes in mm. (4). Catch [1]. (5). Check valve rotary ("flap"). (6). Gasket compensator. (7). one-way. (8). bilateral. (9). Sludge pan is washing. (10). Branch/removals welded single-seam with angle. (11). Branch/removals are welded with angle of 90°. (12). two-seam, R = 1 D. (13). three-seam. (14). Four-seam, R = 1 D. (15). Branch/removals sharply bent. (16). Compensators are U-shaped with welded three-seam branch/removals. (17). Compensators U-shaped with sharply bent branch/removals. (18). Compensator is single-lens. (19). without jacket [2]. (20). With jacket. (21). -piece during the separation of flow. (22). pass [3]. (23). branch. (24). -piece with the merging/coalescence of flow. (25). -pieces. (26). with the diverging flow. (27). with counterflow. (28). Transfer/transitions welded (MN 2883-62): [4].

Pages 150 and 151.

Values γ_{cp} are determined from formula (9.32).

With the assigned/prescribed specific loss of pressure on friction Δh_A or speed pair v_A for the use of nomograms or the tables of their value they are recounted by the formulas:

$$\Delta h = \Delta h_A \gamma_{cp} \text{ kgf/m}^2 \text{ m}; \quad (9.39)$$

$$v = v_A \gamma_{cp} \text{ m/s}. \quad (9.40)$$

For hydraulic design of steam lines, they compose the design diagram of steam line (see Fig. 9.12).

Calculated section is considered the section between two nearest branches. During calculation of steam lines a large quantity of branches the length of calculated section accepts equal from 300 to 500 m. With large superheating pair the length of calculated section can be increased to 1000 m.

First of all is performed the calculation of the basic calculated main line for which the value of the available specific loss of pressure on friction Δh_p, determined by

formula (9.35), has small value, and then are designed branches.

Steam lines are designed by trial-and-error method.

They are preliminarily assigned by mean temperature and average specific gravity/weight pair on section, and for the selected diameter of pipeline are determined the final parameters pair. If in this case average specific gravity/weight pair and mean temperature on section differ from the taken preliminarily, latter one should refine and repeat calculation and refinement until the taken parameters coincide with calculated. In these parameters are determined the losses of pressure and temperature pair on section.

Hydraulic design of steam lines performs according to the forms, which reflect the specific character of the calculation of the pipelines of the saturated steam (Table 9.22) and of the superheated steam (Table 9.23).

An example of hydraulic design of the steam line of the superheated steam for circuit Fig. 9.12 is given in Table 9.23.

9.6. Hydraulic design of condensate pipings.

Hydraulic design of forcing condensate pipings can be performed on Table 9.24 and nomograms Figs. 9.13 and 9.14.

During the compilation of tables and nomograms for forcing condensate pipings, are accepted: the temperature of condensate t = 100°C, the specific gravity/weight of condensate γ = 958.4 kg/m³, equivalent roughness $k_э$=1 mm and kinematic viscosity $\nu=0.295\cdot10^{-6}$ m²/s. At the values of equivalent roughnesses and tube bores, which differ from the taken during compilation tables and nomograms, values Δh, v and $l_э$ obtained from tables or nomograms, they recount by formulas (9.23)-(9.26), (9.29)-(9.31).

During hydraulic designs of forcing condensate pipings, specific losses of pressure on friction are accepted to 10 kgf/m² m.

Hydraulic calculation of forcing condensate pipings are performed of analogous with hydraulic design water thermal grid/networks.

Hydraulic design of composite condensate pipings is performed on Table 9.24 or on nomograms Figs. 9.13 and 9.14, in this case the obtained values of loss of pressure on friction and speeds are multiplied by coefficient ϕ:

$$\Delta h_{см} = \Delta h \varphi \quad \text{kgf/m}^2 \text{ m}; \tag{9.43}$$

$$v_{см} = v\varphi \quad \text{m/s}, \tag{9.44}$$

where ϕ is a coefficient of an increase in the loss of pressure on friction and the speeds in condensate piping during the transportation of steam-water mixture;

Δh - specific loss of pressure on friction in kgf/m² m, determined by tables or nomograms for the calculation of condensate pipings with γ = 958.4 kg/m³;

v - the speed in m/s, determined by tables or nomograms for the calculation of condensate pipings with γ = 958.4 kg/m³.

Table 9.22. Form of table for hydraulic design of the pipelines of the saturated steam.

(14) № участков	(5) Расход пара G в $т/ч$	(1) Характеристика трубы: (6) условный проход D_y в $мм$	(7) наружный диаметр в $мм$ × толщина стенки трубы $D_н \times s$ в $мм$	(2) Длина участка трубопровода в $м$: (8) по плану l	(9) эквивалентная местным сопротивлениям $l_э$	(10) приведенная $l_{пр}$	(3) Начало участка: (11) давление $P_н$ в $кгс/см^2$	(12) удельный вес $\gamma_н$ в $кгс/м^3$	(3a) При $\gamma = 1$ $кгс/м^3$: (13) скорость v в $м/сек$	(14) удельная потеря давления на трение Δh в $кгс/м^2 м$
1	2	3	4	5	6	7	8	9	10	11

(15) Предполагаемый средний удельный вес $\gamma_{ср}$ в $кгс/м^3$	(3a) При $\gamma_{ср}$ $кгс/м^3$: (16) скорость $v_д = \frac{v}{\gamma_{ср}}$ в $м/сек$	(17) потеря давления: (22) удельная $\Delta h_д = \frac{\Delta h}{\gamma_{ср}}$ в $кгс/м^2 м$	(23) на участке $\Delta H = \Delta h_д l_{пр}$ в $кгс/м^2$	(3b) Конец участка: (18) давление $P_к$ в $кгс/см^2$	(19) удельный вес $\gamma_к$ в $кгс/м^3$	(20) Средний удельный вес пара $\gamma_{ср}$ в $кгс/м^3$	(21) Суммарная потеря давления от ГЭЦ $H = \Sigma \Delta H \cdot 10^{-4}$ в $кгс/см^2$
12	13	14	15	16	17	18	19

Key: [Key reads left to right]. (1). Characteristic of tube. (2). Length of the section of pipeline in m. (3). Beginning of section. (3a). With $\gamma = /$ kg/m³. (3b). End of the section. (4). No sections. (5). Consumption is pair G in t/h. (6). the internal diameter D_y in mm. (7). outside

diameter in mm x the wall thickness of tube D_H x s in mm. (8). according to the plan l. (9). equivalent to local resistance $l_э$. (10). given $l_{пр}$. (11). pressure P_H in kg/cm². (12). specific gravity/weight γ_H in kg/m³. (13). speed v in m/s. (14). specific loss of pressure on friction Δh in kgf/m² m. (15). Predicted average specific gravity/weight $\gamma_{ср}$ in kg/m³. (16). the speed $v_A = \frac{v}{\gamma_{ср}}$ in m/s. (17). loss of pressure. (18). pressure P_K in kg/m³. (19). specific gravity/weight γ_K in kg/m³. (20). Average specific gravity/weight is pair $\gamma_{ср}$ in kg/m³. (21). Total loss of pressure from heat and power plant $H = \Sigma \Delta H \cdot 10^{-4}$ in kg/cm². (22). specific $\Delta h_A = \frac{\Delta h}{\gamma_{ср}}$ in kgf/m² m. (23). on section $\Delta H = \Delta h_A l_{пр}$ in kgf/m².

Table 9.23. Form of table and an example of hydraulic design of the pipelines of the superheated steam.

(4) № участков	(5) Расход пара G в т/ч	(1) Характеристика трубы: (6) условный проход D_y в мм	(7) наружный диаметр в мм × толщина стенки трубы в мм $D_н \times s$	(2) Длина участка трубопровода в м: (8) по плану l	(9) эквивалентная местным сопротивлениям $l_э$	(10) приведенная $l_{пр}$	(3) Начало участка: (11) давление $P_н$ в кгс/см²	(12) температура $t_н$ в град	(13) удельный вес $\gamma_н$ в кгс/м³	(3а) При $\gamma = 1$ кгс/м³: (14) скорость v в м/сек	(15) удельная потеря давления на трение Δh в кгс/м²м
1	2	3	4	5	6	7	8	9	10	11	12
										(28) Основная расчетная	
ТЭЦ-1	45	300	325×8	1000	800	1800	13	300	4,98	167	81,1
1-А	25	250	273×7	400	320	720	9,67	284,8	3,79	132	63,1
										(29) Ответ	
1—В	20	250	273×7	600	480	1080	9,67	284,8	3,79	106	40,4

(16) Предполагаемый средний удельный вес $\gamma_{ср}$ в кгс/м³	(3б) При $\gamma_{ср}$ в кгс/м³: (17) скорость $v_д = \frac{v}{\gamma_{ср}}$ в м/сек	(18) потеря давления: удельная $\Delta h_д = \frac{\Delta h}{\gamma_{ср}}$ (24) в кгс/м²м	на участке $\Delta H = \Delta h_д \times l_{пр}$ (27) в кгс/м²	(3в) Потеря тепла: (19) удельная $q_{уд}$ в ккал/м ч град	(20) суммарная q в ккал/ч	(21) Падение температуры Δt в град	(3г) Конец участка: (22) давление $P_к$ в кгс/см²	(23) температура $t_к$ в град	(24) удельный вес $\gamma_к$ в кгс/м³	(25) Средний удельный вес $\gamma_{ср}$ кгс/м³	(3д) Суммарная потеря давления от ТЭЦ $H = \Sigma \Delta H \times 10^{-4}$ в кгс/см²
13	14	15	16	17	18	19	20	21	22	23	24
магистраль											
4,4	37,2	18,5	33300	1,14	356	15,2	9,67	284,8	3,79	4,39	3,33
3,57	37	17,7	12700	1,03	124	9,7	8,4	275,1	3,34	3,57	4,6
ление											
3,64	29,1	11,1	12000	1,03	183	18	8,47	266,8	3,48	3,64	4,53

Key: [Key reads from left to right]. (1). Characteristic of tube. (2). Length of the section of pipeline in m. (3). Beginning of section (3a). With $\gamma = 1$ kg/m³. (3b). Heat loss. (3c). End of the section. (3d). Total loss of pressure from heat and power plant $H = \Sigma \Delta H \times 10^{-4}$ in kg/cm². (4). No

sections. (5). Consumption is pair G in t/h. (6). conditional passage D_y in mm. (7). outside diameter in mm x the wall thickness of tube in mm $D_н \times s$. (8). according to the plan l. (9). equivalent to local resistance $l_э$. (10). presented $l_{пр}$. (11). pressure $P_н$ in kg/cm². (12). the temperature $t_н$ in deg. (13). specific gravity/weight $\gamma_н$ in kg/m³. (14). speed v in m/s. (15). specific loss of pressure on friction Δh in kgf/m² m. (16). Predicted average specific gravity/weight $\gamma'_{ср}$ in kg/m³. (17). the speed $v_д = \frac{v}{\gamma_{ср}}$ in m/s. (18). loss of pressure. (19). specific $q_{ун}$ in kcal/m h deg. (20). total Q in kcal/h. (21). Temperature drop Δt in deg. (22). pressure $P_к$ in kg/cm². (23). the temperature $t_к$ in deg. (24). specific gravity/weight $\gamma_к$ in kg/m³. (25). Average specific gravity/weight $\gamma_{ср}$ in kg/m³. (26). specific $\Delta h_д = \frac{\Delta h}{\gamma_{ср}}$ in kgf/m² m. (27). on section $\Delta H = \Delta h_д \times l_{пр}$ in kgf/m². (28). Basic calculated main line. (29). Branch.

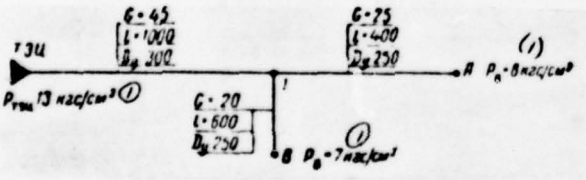


Fig. 9.12. The design diagram of steam lines. G - consumption is pair in t/h; l - the length of calculated section in m; D_y - the internal diameter of pipeline in mm.

Key: (1). kg/cm².

Page 152.

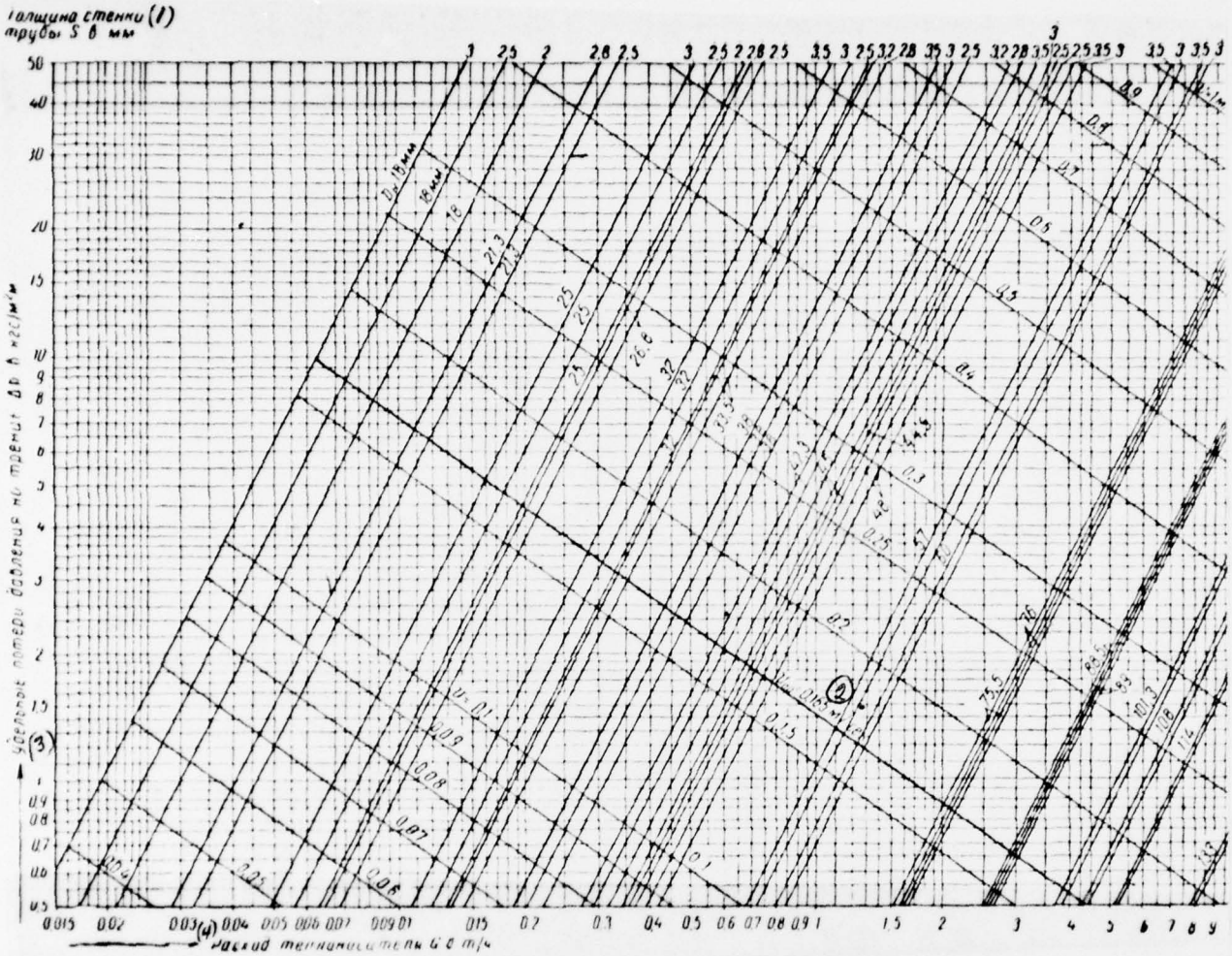


Fig. 9.13. Nomogram for hydraulic design of pipelines with $k_э = 1$ mm and γ = 958 kG/m³ with coolant flow rate from 0.015 to 10 t/hs. Bold line designates the maximum speed $v_{пр} = 0,165$ λ m/s, which corresponds to the boundary/interface between the transfer and quadratic range.

Key: (1). The wall thickness of tube S in mm. (2). m/s. (3). Specific losses of pressure but friction Δh in kgf/m² m. (4). Coolant flow rate G in t/h.

page 153.

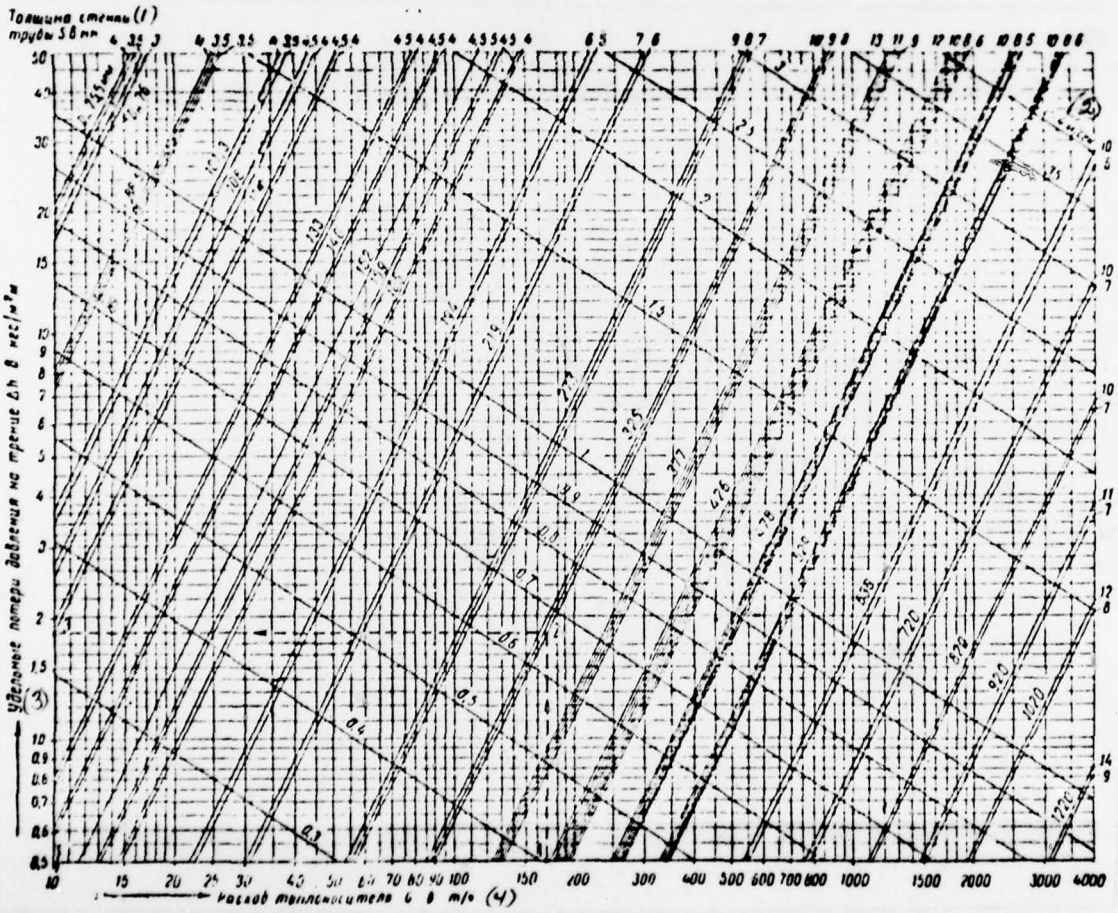


Fig. 9.14. Nomogram for hydraulic design of pipelines with $k_э = 1$ mm and γ = 958 kG/m³ with coolant flow rate from 10 to 4000 t/hs.

Example. It is given to G = 170 t/hs; $D_н$-325 мм; s = 8 мм. We find in point 2 v = 0.66 m/s and in point 3 Δh = 1.82 kgf/m² m.

Key: (1). The wall thickness of tube S in mm. (2). m/s. (3). Specific losses of pressure on friction Δh in kgf/m² m. (4). Coolant flow rate is G in t/h.

Pages 154-159.

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Table 9.24. Table for hydraulic design of condensator lines with $k_э$=1 mm, γ = 958.4 kG/m³.

$D_н \times s$ мм (1) / G (2) т/ч	32×2.5		38×2.5		44.5×2.5		45×2.5		57×3.5	
	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м
0.2	0.1	1.2								
0.22	0.11	1.48								
0.24	0.12	1.76								
0.26	0.13	2.04								
0.28	0.14	2.35								
0.3	0.15	2.7	0.1	0.91						
0.32	0.16	3.05	0.11	1.05						
0.34	0.17	3.35	0.12	1.17						
0.36	0.18	3.75	0.12	1.33						
0.38	0.19	4.18	0.13	1.46						
0.4	0.2	4.63	0.14	1.59	0.095	0.64	0.092	0.58		
0.42	0.21	5.11	0.14	1.78	0.1	0.69	0.097	0.64		
0.44	0.22	5.61	0.15	1.93	0.1	0.76	0.10	0.71		
0.46	0.23	6.13	0.16	1.07	0.11	0.84	0.11	0.77		
0.48	0.24	6.67	0.16	2.25	0.11	0.91	0.11	0.84		
0.5	0.25	7.24	0.17	2.44	0.12	0.96	0.12	0.89		
0.55	0.28	8.76	0.19	2.95	0.13	1.14	0.13	1.07		
0.6	0.3	10.4	0.2	3.51	0.14	1.36	0.14	1.26		
0.65	0.33	12.2	0.22	4.12	0.15	1.53	0.15	1.46		
0.7	0.35	14.2	0.24	4.77	0.17	1.81	0.16	1.69	0.1	0.53
0.75	0.38	16.3	0.25	5.48	0.18	2.07	0.17	1.94	0.11	0.61
0.8	0.41	18.5	0.27	6.24	0.19	2.36	0.18	2.2	0.12	0.7
0.85	0.43	20.9	0.29	7.04	0.2	2.66	0.20	2.49	0.13	0.77
0.9	0.46	23.5	0.31	7.9	0.21	2.99	0.21	2.79	0.13	0.87
0.95	0.48	26.1	0.32	8.8	0.24	3.33	0.22	3.11	0.14	0.97
1	0.51	29	0.34	9.75	0.24	3.69	0.23	3.44	0.15	1.06
1.05	0.53	31.9	0.36	10.7	0.25	4.06	0.24	3.8	0.16	1.16
1.1	0.56	35	0.37	11.8	0.26	4.46	0.25	4.17	0.16	1.26
1.15	0.58	38.3	0.39	12.9	0.27	4.88	0.27	4.56	0.17	1.37
1.2	0.61	41.7	0.41	14	0.28	5.3	0.28	4.96	0.18	1.49

Continuation Table 9.24.

$D_н \times s$ мм (1) / G (2) т/ч	38×2.5		44.5×2.5		45×2.5		57×3.5		76×3.5		89×3.5	
	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м	(3) v м/сек	(4) Δh кгс/м²м
1.25	0.42	15.2	0.3	5.76	0.29	5.38	0.18	1.62				
1.3	0.44	16.5	0.31	6.23	0.3	5.82	0.19	1.75				
1.35	0.46	17.8	0.32	6.72	0.31	6.28	0.2	1.89				
1.4	0.47	19.1	0.33	7.23	0.32	6.75	0.21	2.03				
1.45	0.49	20.5	0.34	7.75	0.33	7.24	0.21	2.17				
1.5	0.51	21.9	0.36	8.3	0.35	7.75	0.22	2.33	0.12	0.43		
1.55	0.53	23.4	0.37	8.86	0.36	8.28	0.23	2.49	0.12	0.47		
1.6	0.54	25	0.38	9.44	0.37	8.82	0.24	2.65	0.12	0.5		
1.65	0.56	26.5	0.39	10	0.38	9.38	0.24	2.82	0.13	0.52		
1.7	0.58	28.2	0.4	10.7	0.39	9.96	0.25	2.99	0.13	0.55		
1.75	0.59	29.9	0.41	11.3	0.4	10.5	0.26	3.17	0.14	0.58		
1.8	0.61	31.6	0.43	11.9	0.42	11.2	0.27	3.35	0.14	0.62		
1.85	0.63	33.4	0.44	12.6	0.43	11.8	0.27	3.54	0.14	0.65		
1.9	0.64	35.2	0.45	13.3	0.44	12.4	0.28	3.73	0.15	0.68		
1.95	0.66	37.1	0.46	14	0.45	13.1	0.29	3.93	0.15	0.72		
2	0.68	39	0.47	14.7	0.46	13.8	0.3	4.14	0.16	0.75	0.11	0.3
2.1	0.71	43	0.5	16.3	0.48	15.2	0.31	4.56	0.16	0.81	0.12	0.33
2.2	0.75	47.2	0.52	17.8	0.51	16.7	0.33	5	0.17	0.89	0.12	0.36
2.3	0.78	51.6	0.54	19.5	0.53	18.2	0.34	5.47	0.18	0.97	0.13	0.39
2.4	0.81	56.2	0.57	21.2	0.55	19.8	0.35	5.96	0.19	1.05	0.13	0.43
2.5	0.85	60.9	0.59	23	0.58	21.5	0.37	6.47	0.19	1.15	0.14	0.46
2.6	0.88	65.9	0.62	24.9	0.6	23.3	0.38	6.99	0.2	1.24	0.14	0.5
2.7	0.92	71.1	0.64	26.9	0.62	25.1	0.4	7.54	0.21	1.31	0.15	0.54
2.8	0.95	76.4	0.66	28.9	0.65	27	0.41	8.11	0.22	1.44	0.15	0.58
2.9	0.98	82	0.69	31	0.67	29	0.43	8.7	0.22	1.54	0.16	0.62
3	1	87.7	0.71	33.2	0.69	31	0.44	9.31	0.23	1.65	0.16	0.66
3.1	1.05	93.7	0.73	35.4	0.72	33.1	0.46	9.94	0.24	1.76	0.17	0.7
3.2	1.09	99.8	0.76	37.8	0.74	35.3	0.47	10.6	0.25	1.88	0.18	0.75
3.3	1.12	106.2	0.78	40.2	0.76	37.5	0.49	11.3	0.26	2	0.18	0.79
3.4	1.15	112.7	0.8	42.6	0.78	39.8	0.5	12	0.26	2.12	0.19	0.84

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Continuation Table 9.24.

$D_н \times s$, мм (1)	44,5×2,5		45×2,5		57×3,5		76×3,5		89×3,5		108×4		133×4	
G, т/ч (2)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)
3,5	0,85	47,8	0,81	42,2	0,52	12,7	0,27	2,35	0,19	0,89	0,13	0,33		
3,6	0,88	50,5	0,83	44,6	0,53	13,4	0,28	2,38	0,2	0,94	0,13	0,35		
3,7	0,9	53,2	0,85	47,2	0,55	14,2	0,29	2,51	0,2	1	0,14	0,36		
3,8	0,92	56,1	0,88	49,7	0,56	14,9	0,29	2,65	0,21	1,05	0,14	0,37		
3,9	0,92	56,1	0,9	52,4	0,58	15,7	0,3	2,8	0,21	1,11	0,14	0,39		
4	0,95	59	0,92	55,1	0,6	16,6	0,31	2,93	0,22	1,16	0,15	0,41	0,09	0,13
4,2	0,99	65	0,97	60,8	0,62	18,2	0,33	3,23	0,23	1,28	0,16	0,45	0,1	0,14
4,4	1,04	71,4	1,02	66,7	0,65	20	0,34	3,55	0,24	1,41	0,16	0,49	0,1	0,16
4,6	1,09	78,1	1,06	72,9	0,68	21,9	0,36	3,88	0,25	1,54	0,17	0,53	0,11	0,17
4,8	1,14	84,9	1,11	79,4	0,71	23,8	0,37	4,23	0,26	1,68	0,18	0,58	0,11	0,18
5	1,18	92,1	1,15	86,1	0,74	25,9	0,39	4,58	0,27	1,82	0,18	0,63	0,12	0,2
5,2	1,23	99,7	1,2	93,1	0,77	28	0,41	4,96	0,29	1,97	0,19	0,68	0,12	0,22
5,4	1,28	107,3	1,25	100,5	0,8	30,2	0,42	5,35	0,3	2,12	0,2	0,73	0,13	0,23
5,6					0,83	32,4	0,43	5,75	0,31	2,28	0,21	0,79	0,13	0,25
5,8					0,86	34,8	0,45	6,17	0,32	2,45	0,21	0,85	0,14	0,26
6					0,89	37,2	0,47	6,6	0,33	2,61	0,22	0,91	0,14	0,28
6,2					0,92	39,8	0,48	7,05	0,34	2,8	0,23	0,97	0,15	0,3
6,4					0,95	42,4	0,5	7,51	0,35	2,98	0,24	1,03	0,15	0,32
6,6					0,98	45,1	0,51	7,99	0,36	3,17	0,24	1,1	0,16	0,34
6,8					1	47,8	0,53	8,48	0,37	3,36	0,25	1,17	0,16	0,36
7					1,03	50,7	0,54	8,99	0,38	3,57	0,26	1,23	0,17	0,38
7,5					1,11	58,2	0,58	10,3	0,41	4,09	0,28	1,42	0,18	0,43
8					1,18	66,2	0,62	11,7	0,44	4,66	0,3	1,61	0,19	0,49
8,5					1,26	74,7	0,66	13,2	0,47	5,26	0,31	1,82	0,2	0,55
9					1,33	83,8	0,7	14,9	0,49	5,89	0,33	2,04	0,21	0,62
9,5					1,4	93,4	0,74	16,5	0,52	6,57	0,35	2,27	0,22	0,69
10					1,48	103,4	0,78	18,3	0,55	7,28	0,37	2,52	0,24	0 77
10,5							0,81	20,2	0,58	8,02	0,39	2,78	0,25	0,85
11							0,85	22,2	0,6	8,8	0,41	3,05	0,26	0,93
11,5							0,89	24,3	0,63	9,62	0,42	3,33	0,27	1,01

Continuation Table 9.24.

$D_н \times s$, мм (1)	76×3,5		89×3,5		108×4		133×4		152×4,5		159×4,5		194×6		194×5		219×7		219×6	
G, т/ч (2)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)	v, м/сек (3)	Δh, кгс/м² (4)
12	0,97	28,7	0,66	10,5	0,44	3,63	0,28	1,1	0,22	0,54	0,2	0,42								
12,5	1,01	31	0,69	11,4	0,46	3,94	0,3	1,2	0,23	0,59	0,21	0,45								
13	1,05	33,4	0,71	12,3	0,48	4,26	0,31	1,3	0,23	0,63	0,21	0,49								
13,5	1,09	35,9	0,74	13,3	0,5	4,59	0,32	1,4	0,24	0,68	0,22	0,53								
14	1,12	38,6	0,77	14,3	0,52	4,94	0,33	1,5	0,25	0,73	0,23	0,57								
14,5	1,16	41,3	0,8	15,3	0,54	5,3	0,34	1,61	0,26	0,79	0,24	0,61								
15	1,16	41,3	0,82	16,4	0,55	5,67	0,35	1,73	0,27	0,84	0,25	0,65	0,17	0,23						
16	1,24	46,9	0,88	18,6	0,59	6,45	0,38	1,96	0,29	0,96	0,26	0,74	0,18	0,27	0,17	0,25				
17	1,32	53	0,93	21	0,63	7,28	0,4	2,22	0,31	1,08	0,28	0,84	0,19	0,3	0,19	0,28				
18	1,4	59,4	0,99	23,6	0,66	8,16	0,43	2,48	0,33	1,21	0,3	0,94	0,2	0,34	0,2	0,32				
19	1,47	66,2	1,04	26,3	0,7	9,1	0,45	2,77	0,34	1,35	0,31	1,05	0,21	0,38	0,21	0,35	0,17	0,2		
20	1,55	73,4	1,1	29,1	0,74	10,1	0,47	3,07	0,36	1,5	0,33	1,16	0,22	0,42	0,22	0,39	0,18	0,22	0,17	0,21
21	1,63	80,9	1,15	32,1	0,78	11,1	0,5	3,38	0,33	1,65	0,34	1,28	0,23	0,46	0,23	0,43	0,18	0,24	0,18	0,23
22	1,71	88,8	1,21	35,2	0,81	12,2	0,52	3,71	0,4	1,81	0,36	1,41	0,25	0,5	0,24	0,48	0,19	0,27	0,19	0,25
23	1,78	97	1,26	38,5	0,85	13,3	0,54	4,06	0,42	1,98	0,38	1,54	0,26	0,55	0,25	0,52	0,2	0,29	0,2	0,28
24	1,86	105,6	1,32	41,9	0,89	14,5	0,57	4,42	0,43	2,16	0,39	1,67	0,27	0,6	0,26	0,57	0,21	0,32	0,21	0,3
25			1,37	45,5	0,92	15,7	0,59	4,79	0,45	2,34	0,41	1,82	0,28	0,65	0,27	0,61	0,22	0,35	0,22	0,33
26			1,43	49,2	0,96	17,0	0,61	5,18	0,47	2,53	0,43	1,96	0,29	0,7	0,28	0,66	0,23	0,37	0,22	0,36
27			1,48	53	1	18,4	0,64	5,59	0,49	2,73	0,44	2,12	0,3	0,76	0,3	0,7	0,24	0,4	0,23	0,38
28			1,54	57	1,03	19,8	0,66	6,01	0,51	2,94	0,46	2,28	0,31	0,82	0,31	0,77	0,25	0,43	0,24	0,41
29			1,59	61,2	1,07	21,2	0,69	6,45	0,52	3,15	0,48	2,44	0,32	0,88	0,32	0,83	0,25	0,47	0,25	0,44
30			1,65	65,5	1,11	22,7	0,71	6,9	0,51	3,37	0,49	2,62	0,33	0,94	0,33	0,88	0,26	0,5	0,25	0,47
31			1,7	69,9	1,15	24,2	0,73	7,37	0,53	3,6	0,51	2,79	0,35	1	0,34	0,94	0,27	0,53	0,27	0,51
32			1,76	74,5	1,18	25,8	0,76	7,85	0,58	3,84	0,53	2,98	0,36	1,07	0,35	1	0,28	0,57	0,28	0,54
33			1,81	79,2	1,22	27,4	0,78	8,35	0,6	4,08	0,54	3,16	0,37	1,13	0,36	1,07	0,29	0,6	0,28	0,57
34			1,87	84,1	1,26	29,1	0,8	8,86	0,61	4,33	0,56	3,36	0,38	1,2	0,37	1,14	0,3	0,64	0,29	0,61
35			1,92	89,1	1,29	30,9	0,83	9,39	0,63	4,59	0,57	3,56	0,39	1,27	0,38	1,2	0,31	0,68	0,3	0,64
36			1,98	94,3	1,33	32,7	0,85	9,94	0,65	4,86	0,59	3,77	0,4	1,35	0,39	1,27	0,32	0,72	0,31	0,68
37			2,03	99,6	1,37	34,5	0,87	10,5	0,67	5,13	0,61	3,98	0,41	1,42	0,4	1,34	0,33	0, 6	0,32	0,72
38			20,9	105	1,4	36,4	0,9	11,1	0,69	5,41	0,62	4,2	0,42	1,5	0,41	1,42	0,33	0,8	0,33	0,76

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Continuation Table 9.24.

$D_н \times s$ мм (1)	108×4		133×4		152×4,5		159×4,5		194×6		194×5		219×7		219×6		273×8		273×7		325×8	
G (2) т/ч	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м
39	1,4	38,3	0,92	14,7	0,7	5,7	0,64	4,42	0,43	1,58	0,43	1,49	0,34	0,84	0,34	0,8	0,22	0,25	0,21	0,24		
40	1,5	40,3	0,95	12,3	0,72	5,6	0,66	4,65	0,45	1,66	0,44	1,57	0,35	0,89	0,35	0,84	0,22	0,27	0,22	0,26		
41	1,51	42,4	0,97	12,9	0,74	6,3	0,67	4,89	0,46	1,75	0,45	1,65	0,36	0,93	0,35	0,88	0,23	0,28	0,23	0,27		
42	1,55	44,4	0,99	13,5	0,76	6,61	0,69	5,13	0,47	1,84	0,46	1,73	0,37	0,98	0,36	0,93	0,23	0,29	0,23	0,28		
43	1,59	46,6	1,02	14,2	0,78	6,93	0,71	5,37	0,48	1,92	0,47	1,82	0,38	1,02	0,37	0,97	0,24	0,31	0,24	0,3		
44	1,63	48,8	1,04	14,8	0,79	7,25	0,72	5,63	0,49	2,01	0,48	1,9	0,39	1,07	0,38	1,02	0,25	0,32	0,24	0,31		
45	1,66	51	1,06	15,5	0,81	7,59	0,74	5,89	0,5	2,11	0,49	1,99	0,4	1,12	0,39	1,06	0,25	0,34	0,25	0,32		
46	1,7	53,3	1,09	16,2	0,83	7,93	0,76	6,15	0,51	2,2	0,5	2,08	0,4	1,17	0,4	1,11	0,26	0,35	0,25	0,34		
47	1,74	55,7	1,11	16,9	0,85	8,28	0,77	6,42	0,52	2,3	0,51	2,17	0,41	1,22	0,41	1,16	0,26	0,37	0,26	0,35		
48	1,77	58,1	1,13	17,7	0,87	8,63	0,79	6,7	0,54	2,4	0,52	2,26	0,42	1,28	0,41	1,21	0,27	0,39	0,26	0,37		
49	1,81	60,5	1,16	18,4	0,89	9	0,8	6,98	0,55	2,5	0,53	2,36	0,43	1,33	0,42	1,26	0,27	0,4	0,27	0,39		
50	1,85	63	1,18	19,2	0,9	9,37	0,82	7,27	0,56	2,6	0,55	2,45	0,44	1,38	0,43	1,31	0,28	0,42	0,28	0,4	0,19	0,16
52	1,92	68,1	1,23	20,7	0,94	10,1	0,85	7,86	0,58	2,81	0,57	2,66	0,46	1,41	0,45	1,42	0,29	0,45	0,29	0,43	0,2	0,17
54	1,99	73,5	1,28	22,4	0,98	10,9	0,89	8,47	0,6	3,03	0,59	2,86	0,47	1,61	0,47	1,51	0,3	0,49	0,3	0,47	0,21	0,18
56	2,07	79	1,32	24	1,01	11,8	0,92	9,11	0,62	3,26	0,61	3,08	0,49	1,74	0,48	1,65	0,31	0,5	0,31	0,5	0,22	0,2
58	2,14	84,8	1,37	25,8	1,05	12,6	0,95	9,78	0,65	3,5	0,63	3,3	0,51	1,84	0,5	1,77	0,32	0,56	0,32	0,54	0,23	0,21
60	2,22	90,7	1,42	27,6	1,08	13,5	0,98	10,5	0,67	3,75	0,65	3,53	0,53	1,99	0,52	1,89	0,34	0,6	0,33	0,5	0,23	0,23
62	2,29	96,9	1,47	29,5	1,11	14,4	1,02	11,2	0,69	3,4	0,68	3,77	0,54	2,12	0,53	2,02	0,35	0,64	0,34	0,62	0,24	0,24
64	2,36	103,2	1,51	31,4	1,12	15,3	1,05	11,9	0,71	4,26	0,7	4,02	0,56	2,26	0,55	2,15	0,36	0,68	0,35	0,66	0,25	0,26
66			1,56	33,4	1,15	16,3	1,08	12,7	0,74	4,53	0,72	4,28	0,58	2,41	0,57	2,3	0,37	0,73	0,36	0,7	0,26	0,27
68			1,61	35,5	1,22	17,3	1,12	13,4	0,76	4,81	0,74	4,54	0,6	2,62	0,59	2,43	0,38	0,77	0,37	0,74	0,28	0,29
70			1,65	37,6	1,26	18,4	1,15	14,2	0,78	5,1	0,76	4,81	0,62	2,71	0,6	2,54	0,39	0,82	0,39	0,79	0,27	0,31
72			1,7	39,7	1,3	19,4	1,18	15,1	0,8	5,39	0,79	5,09	0,63	2,87	0,62	2,73	0,4	0,87	0,4	0,83	0,28	0,33
74			1,75	42	1,34	20,5	1,21	15,9	0,83	5,69	0,81	5,38	0,65	3,03	0,64	2,88	0,41	0,92	0,41	0,88	0,29	0,35
76			1,8	44,3	1,37	21,6	1,25	16,8	0,85	6,01	0,83	5,67	0,67	3,2	0,66	3,04	0,43	0,97	0,4	0,93	0,29	0,36
78			1,84	46,6	1,41	22,8	1,28	17,7	0,87	6,33	0,85	5,97	0,69	3,37	0,67	3,2	0,43	1,02	0,43	0,98	0,3	0,38
80			1,89	49,1	1,45	24	1,31	18,6	0,89	6,65	0,87	6,28	0,7	3,54	0,69	3,36	0,45	1,07	0,44	1,03	0,31	0,4
85			2,01	55,4	1,54	27,1	1,4	21	0,95	7,52	0,93	7,09	0,75	3,4	0,73	3,3	0,48	1,21	0,47	1,16	0,33	0,46
90			2,13	62,1	1,63	30,4	1,48	23,5	1	8,43	0,98	7,95	0,79	4,48	0,78	4,26	0,5	1,35	0,5	1,3	0,35	0,51
95			2,25	69,2	1,72	33,8	1,56	26,2	1,05	9,4	1,04	8,86	0,83	5	0,82	4,74	0,53	1,51	0,52	1,45	0,37	0,57

Continuation Table 9.24.

$D_н \times s$ мм (1)	152×4,5		159×4,5		194×6		194×5		219×7		219×6		273×8	
G (2) т/ч	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м	(3) v м/сек	(4) Δh м вод. ст./м
100	1,81	37,5	1,64	29,1	1,12	10,4	1,09	9,82	0,88	5,54	0,86	5,26	0,56	1,67
105	1,89	41,3	1,72	32	1,17	11,5	1,15	10,8	0,92	6,1	0,91	5,8	0,59	1,84
110	1,99	45,3	1,81	35,2	1,23	12,6	1,2	11,9	0,97	6,7	0,95	6,35	0,62	2,02
115	2,08	49,6	1,89	38,4	1,28	13,8	1,25	13	1,01	7,32	0,99	6,95	0,64	2,21
120	2,17	54	1,97	41,8	1,34	15	1,31	14,1	1,05	7,97	1,03	7,57	0,67	2,41
125	2,26	58,5	2,05	45,4	1,39	16,3	1,36	15,3	1,1	8,65	1,08	8,21	0,7	2,61
130	2,35	63,3	2,13	49,1	1,45	17,6	1,42	16,6	1,14	9,35	1,12	8,89	0,73	2,82
135	2,44	68,3	2,22	53	1,51	19	1,47	17,9	1,19	10,1	1,16	9,58	0,75	3,05
140	2,53	73,4	2,3	57	1,56	20,4	1,53	19,2	1,23	10,8	1,21	10,3	0,78	3,28
145	2,62	78,8	2,31	61,1	1,62	21,9	1,58	20,6	1,27	11,6	1,25	11,1	0,81	3,51
150	2,7	84,3	2,46	65,4	1,67	23,4	1,64	22,1	1,32	12,5	1,29	11,8	0,84	3,76
155	2,8	90	2,54	69,8	1,73	25	1,69	23,6	1,35	13,3	1,34	12,6	0,87	4,02
160	2,89	95,9	2,63	74,4	1,78	26,6	1,75	25,1	1,41	14,2	1,38	13,5	0,89	4,28
165	2,98	102	2,71	79,1	1,84	28,3	1,8	26,7	1,45	15,1	1,42	14,3	0,92	4,55
170			2,79	84	1,9	30,1	1,8	28,4	1,49	16	1,47	15,2	0,95	4,83
175			2,87	89	1,95	31,9	1,91	30,1	1,54	17	1,51	16,1	0,98	5,12
180			2,95	94,2	2,01	33,7	1,96	31,8	1,58	17,9	1,55	17	1,01	5,42
190					2,12	37,6	2,07	35,4	1,67	20	1,64	19	1,05	6,03
200					2,23	41,6	2,18	39,3	1,76	22,1	1,72	21	1,12	6,69
210					2,34	45,9	2,29	43,3	1,85	24,4	1,81	23,2	1,17	7,37
220					2,45	51,4	2,4	47,5	1,93	26,8	1,9	25,4	1,23	8,09
230					2,56	55	2,51	51,9	2,02	29,3	1,98	27,8	1,29	8,84
240					2,68	59,9	2,62	56,6	2,11	31,9	2,07	30,3	1,34	9,63
250					2,79	65	2,73	61,4	2,2	34,6	2,16	32,8	1,4	10,4
260					2,9	70,3	2,84	65,4	2,29	37,4	2,24	35,5	1,45	11,3
270					3,01	75,9	2,95	72,6	2,37	40,4	2,33	38,3	1,51	12,2
280					3,12	81,6	3,05	77	2,46	43,4	2,41	41,2	1,57	13,1
290					3,23	87,5	3,16	82,6	2,55	46,5	2,5	44,2	1,62	14,1
300					3,35	93,6	3,27	88,4	2,64	49,8	2,59	47,3	1,68	15
310					3,46	100	3,38	94,4	2,72	53,2	2,67	50,5	1,73	16,1

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Continuation Table 9.24.

$D_н \times s$ мм	273×7		325×8		377×9		426×10		426×7		426×6		478×7		478×6	
G т/ч	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²
100	0,55	1,6	[illegible]	0,63	0,29	0,29	0,22	0,15	0,22	0,14	0,22	0,13	0,17	0,07	0,17	0,07
105	0,58	1,77	0,11	0,7	0,3	0,32	0,24	0,16	0,23	0,15	0,23	0,15	0,18	0,08	0,17	0,07
110	0,61	1,91	0,43	0,76	0,32	0,35	0,25	0,18	0,24	0,17	0,24	0,16	0,19	0,09	0,19	0,09
115	0,63	2,12	0,44	0,83	0,33	0,38	0,26	0,2	0,25	0,18	0,25	0,18	0,2	0,1	0,2	0,1
120	0,66	2,31	0,46	0,91	0,34	0,41	0,27	0,22	0,26	0,2	0,26	0,19	0,21	0,11	0,2	0,1
125	0,69	2,51	0,48	0,99	0,36	0,45	0,28	0,23	0,27	0,22	0,27	0,21	0,21	0,12	0,21	0,11
130	0,72	2,71	0,5	1,07	0,37	0,48	0,29	0,25	0,28	0,23	0,28	0,23	0,22	0,12	0,22	0,12
135	0,74	2,92	0,52	1,15	0,39	0,52	0,3	0,27	0,29	0,25	0,29	0,25	0,23	0,13	0,23	0,13
140	0,77	3,14	0,54	1,24	0,4	0,56	0,31	0,29	0,3	0,27	0,3	0,26	0,24	0,14	0,24	0,14
145	0,8	3,37	0,56	1,32	0,42	0,6	0,32	0,31	0,32	0,29	0,31	0,28	0,25	0,16	0,25	0,15
150	0,83	3,61	0,58	1,41	0,43	0,64	0,34	0,34	0,33	0,31	0,32	0,3	0,26	0,17	0,26	0,16
155	0,85	3,85	0,6	1,51	0,44	0,69	0,35	0,36	0,34	0,33	0,33	0,32	0,27	0,18	0,26	0,17
160	0,88	4,11	0,62	1,62	0,46	0,73	0,36	0,38	0,35	0,35	0,34	0,34	0,27	0,19	0,27	0,18
165	0,91	4,37	0,64	1,73	0,47	0,78	0,37	0,41	0,36	0,38	0,36	0,37	0,28	0,2	0,28	0,2
170	0,94	4,64	0,66	1,82	0,49	0,83	0,38	0,43	0,37	0,4	0,37	0,39	0,29	0,21	0,29	0,21
175	0,96	4,91	0,68	1,93	0,5	0,88	0,39	0,46	0,38	0,42	0,38	0,41	0,3	0,23	0,3	0,22
180	0,99	5,2	0,7	2,04	0,52	0,93	0,4	0,48	0,39	0,45	0,39	0,44	0,31	0,24	0,31	0,23
190	1,05	5,79	0,73	2,3	0,54	1,03	0,43	0,54	0,41	0,5	0,41	0,49	0,33	0,27	0,32	0,26
200	1,1	6,41	0,77	2,52	0,57	1,14	0,45	0,6	0,44	0,55	0,43	0,54	0,34	0,3	0,34	0,29
210	1,16	7,08	0,81	2,78	0,6	1,26	0,47	0,66	0,46	0,61	0,45	0,59	0,36	0,33	0,35	0,32
220	1,21	7,77	0,85	3,05	0,63	1,38	0,49	0,72	0,48	0,67	0,47	0,65	0,38	0,36	0,37	0,35
230	1,27	8,49	0,89	3,34	0,66	1,51	0,52	0,79	0,5	0,73	0,5	0,71	0,39	0,39	0,39	0,38
240	1,32	9,24	0,93	3,63	0,69	1,65	0,54	0,86	0,52	0,8	0,52	0,78	0,41	0,43	0,41	0,42
250	1,38	10	0,97	3,94	0,72	1,79	0,56	0,93	0,54	0,86	0,54	0,84	0,43	0,46	0,43	0,45
260	1,43	10,8	1,01	4,27	0,75	1,93	0,58	1,01	0,57	0,93	0,56	0,91	0,45	0,47	0,44	0,49
270	1,49	11,7	1,04	4,6	0,77	2,08	0,61	1,09	0,59	1,01	0,58	0,98	0,46	0,54	0,46	0,53
280	1,54	12,6	1,08	4,94	0,8	2,24	0,63	1,17	0,61	1,08	0,6	1,06	0,48	0,58	0,48	0,57
290	1,6	13,5	1,12	5,3	0,83	2,4	0,65	1,26	0,63	1,16	0,62	1,13	0,5	0,62	0,49	0,61
300	1,65	14,4	1,16	5,68	0,86	2,57	0,67	1,34	0,65	1,24	0,65	1,21	0,51	0,66	0,51	0,65
310	1,71	15,4	1,2	6,06	0,89	2,75	0,69	1,44	0,67	1,33	0,67	1,29	0,53	0,71	0,53	0,7

Continuation Table 9.24.

$D_н \times s$ мм	273×8		273×7		325×8		377×9		426×10		426×7		425×6		478×7		478×6		529×7		529×6		630×8		630×7	
G т/ч	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²	③ q м/сек	④ Δh кгс/м²
320	1,78	17,1	1,76	16,4	1,24	6,46	0,92	2,93	0,72	1,53	0,7	1,42	0,69	1,38	0,55	0,76	0,54	0,74	0,45	0,44	0,44	0,43				
330	1,85	18,2	1,82	17,5	1,28	6,9	0,95	3,11	0,74	1,63	0,72	1,51	0,71	1,47	0,57	0,8	0,56	0,79	0,46	0,46	0,46	0,46				
340	1,9	19,3	1,87	18,5	1,32	7,29	0,97	3,3	0,76	1,73	0,74	1,6	0,73	1,56	0,58	0,85	0,58	0,83	0,47	0,49	0,47	0,48				
350	1,96	20,5	1,93	19,7	1,35	7,73	1	3,5	0,78	1,83	0,76	1,69	0,75	1,65	0,6	0,9	0,6	0,88	0,49	0,52	0,48	0,51				
360	2,01	21,7	1,98	20,8	1,4	8,18	1,03	3,7	0,81	1,94	0,78	1,79	0,78	1,75	0,62	0,96	0,61	0,94	0,5	0,55	0,5	0,54				
370	2,07	22,9	2,04	22	1,43	8,64	1,06	3,91	0,83	2,04	0,81	1,89	0,8	1,84	0,63	1,01	0,63	0,99	0,52	0,58	0,51	0,57				
380	2,13	24,1	2,09	23,2	1,47	9,11	1,09	4,13	0,85	2,16	0,83	2	0,82	1,95	0,65	1,07	0,65	1,04	0,53	0,62	0,53	0,6				
390	2,18	25,4	2,15	24,1	1,51	9,6	1,12	4,35	0,87	2,27	0,85	2,1	0,84	2,05	0,67	1,12	0,66	1,1	0,54	0,65	0,54	0,64				
400	2,24	26,7	2,2	25,7	1,55	10,1	1,15	4,57	0,9	2,39	0,87	2,21	0,86	2,16	0,69	1,18	0,68	1,16	0,56	0,68	0,55	0,67				
410	2,29	28,1	2,26	27	1,59	10,6	1,18	4,8	0,92	2,51	0,89	2,32	0,88	2,26	0,7	1,24	0,7	1,21	0,57	0,72	0,57	0,7				
420	2,35	29,5	2,31	28,3	1,62	11,1	1,2	5,04	0,94	2,63	0,91	2,43	0,91	2,38	0,72	1,3	0,71	1,27	0,58	0,75	0,58	0,74				
430	2,4	30,9	2,37	29,7	1,66	11,7	1,23	5,28	0,96	2,76	0,94	2,56	0,93	2,49	0,74	1,37	0,73	1,34	0,6	0,79	0,59	0,77				
440	2,46	32,4	2,42	31,1	1,7	12,2	1,26	5,53	0,99	2,89	0,96	2,68	0,95	2,61	0,75	1,43	0,75	1,4	0,61	0,83	0,61	0,81				
450	2,52	33,9	2,48	32,5	1,74	12,8	1,29	5,79	1,01	3,02	0,98	2,8	0,97	2,73	0,77	1,5	0,77	1,46	0,63	0,86	0,62	0,85				
460	2,57	35,4	2,53	33,9	1,78	13,4	1,32	6,05	1,03	3,16	1	2,92	0,99	2,85	0,79	1,56	0,78	1,53	0,64	0,9	0,64	0,88				
470	2,63	36,9	2,59	35,4	1,82	13,9	1,35	6,31	1,05	3,3	1,02	3,05	1,01	2,98	0,81	1,63	0,8	1,6	0,65	0,94	0,65	0,92				
480	2,68	38,5	2,64	36,9	1,86	14,5	1,38	6,58	1,08	3,44	1,04	3,18	1,03	3,1	0,82	1,7	0,82	1,66	0,67	0,98	0,66	0,96				
490	2,7	40,1	2,7	38,5	1,9	15,1	1,4	6,86	1,1	3,59	1,07	3,32	1,06	3,23	0,84	1,77	0,83	1,73	0,68	1,02	0,68	1				
500	2,8	41,8	2,75	40,1	1,93	15,8	1,43	7,14	1,12	3,73	1,09	3,46	1,08	3,37	0,86	1,85	0,85	1,81	0,7	1,07	0,69	1,04	0,49	0,42	0,49	0,42
520	2,91	45,2	2,86	43,4	2,01	17,1	1,49	7,73	1,17	4,04	1,13	3,74	1,12	3,64	0,89	2	0,88	1,95	0,72	1,15	0,72	1,13	0,51	0,46	0,51	0,45
540	3,02	48,7	2,97	46,8	2,09	18,4	1,55	8,33	1,21	4,35	1,18	4,03	1,16	3,93	0,93	2,15	0,92	2,11	0,75	1,24	0,75	1,22	0,53	0,49	0,53	0,48
560	3,13	52,4	3,08	50,3	2,17	19,8	1,6	8,96	1,25	4,68	1,22	4,33	1,21	4,22	0,96	2,32	0,95	2,26	0,78	1,34	0,77	1,31	0,55	0,53	0,55	0,52
580	3,24	56,2	3,19	54	2,24	21,2	1,66	9,61	1,3	5,02	1,26	4,65	1,25	4,53	1	2,48	0,99	2,43	0,81	1,43	0,8	1,41	0,57	0,57	0,56	0,56
600	3,36	60,2	3,3	57,8	2,32	22,7	1,72	10,3	1,34	5,38	1,31	4,98	1,29	4,85	1,03	2,66	1,02	2,6	0,84	1,54	0,83	1,5	0,59	0,61	0,58	0,6
620	3,47	64,3	3,41	61,7	2,4	24,3	1,78	11	1,39	5,74	1,35	5,31	1,34	5,18	1,06	2,84	1,05	2,78	0,86	1,64	0,86	1,61	0,61	0,65	0,6	0,64
640	3,58	68,7	3,52	65,7	2,48	25,8	1,83	11,7	1,43	6,12	1,39	5,66	1,38	5,52	1,1	3,03	1,09	2,96	0,89	1,75	0,88	1,71	0,63	0,6	0,62	0,68
660	3,69	72,8	3,63	69,5	2,55	27,5	1,89	12,4	1,48	6,5	1,44	6,02	1,42	5,87	1,13	3,22	1,12	3,15	0,92	1,86	0,91	1,82	0,65	0,74	0,64	0,72
680	3,8	77,3	3,74	74,2	2,63	29,2	1,95	13,2	1,52	6,9	1,48	6,4	1,47	6,3	1,17	3,42	1,16	3,34	0,95	1,97	0,94	1,93	0,67	0,78	0,66	0,77
700	3,91	81,9	3,85	78,6	2,71	30,9	2,01	14	1,57	7,32	1,52	6,77	1,51	6,6	1,2	3,62	1,2	3,54	0,97	2,09	0,97	2,06	0,69	0,83	0,68	0,81
720	4,03	86,7	3,9	83,2	2,79	32,7	2,06	14,8	1,61	7,74	1,57	7,16	1,55	6,98	1,24	3,83	1,22	3,74	1	2,21	0,99	2,17	0,71	0,88	0,7	0,86

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Continuation Table 9.24.

$D_н \times s$ мм (1)	325×8		377×9		426×10		426×7		426×6		478×7		478×6		529×7		529×6		630×8	
G (2) кг/с	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²
740	2,86	34,6	2,12	15,6	1,66	8,18	1,61	7,57	1,59	7,38	1,37	4,05	1,35	3,97	1,03	2,34	1,02	2,29	0,73	0,93
760	2,94	36,4	2,18	16,5	1,7	8,63	1,65	7,98	1,64	7,78	1,4	4,27	1,39	4,17	1,05	2,45	1,05	2,41	0,74	0,98
780	3,02	38,4	2,24	17,4	1,75	9,08	1,7	8,41	1,68	8,2	1,44	4,49	1,43	4,39	1,09	2,6	1,08	2,54	0,76	1,03
800	3,04	40,4	2,29	18,3	1,79	9,55	1,74	8,85	1,72	8,62	1,47	4,73	1,46	4,62	1,11	2,73	1,11	2,67	0,78	1,08
820	3,17	42,4	2,35	19,2	1,84	10	1,78	9,29	1,77	9,06	1,51	4,97	1,49	4,85	1,14	2,87	1,13	2,81	0,8	1,14
840	3,25	44,5	2,41	20,2	1,88	10,5	1,83	9,75	1,81	9,51	1,54	5,21	1,53	5,1	1,17	3,01	1,16	2,95	0,82	1,19
860	3,33	46,7	2,46	21,1	1,93	11	1,87	10,2	1,85	9,96	1,58	5,46	1,46	5,34	1,2	3,15	1,19	3,09	0,84	1,25
880	3,4	48,9	2,52	22,1	1,97	11,6	1,91	10,7	1,9	10,4	1,61	5,72	1,5	5,59	1,23	3,3	1,22	3,24	0,86	1,31
900	3,48	51,1	2,58	23,1	2,01	12	1,96	11,2	1,94	10,9	1,64	5,98	1,53	5,85	1,25	3,45	1,24	3,39	0,88	1,37
920	3,56	53,4	2,64	24,2	2,06	12,6	2	11,7	1,98	11,4	1,68	6,25	1,56	6,11	1,28	3,61	1,27	3,54	0,9	1,43
940	3,64	55,8	2,69	25,3	2,11	13,2	2,05	12,2	2,03	11,9	1,61	6,53	1,6	6,38	1,31	3,77	1,3	3,69	0,92	1,49
960	3,71	58,1	2,75	26,3	2,15	13,8	2,09	12,7	2,07	12,4	1,65	6,81	1,63	6,66	1,34	3,93	1,33	3,85	0,94	1,55
980	3,79	60,6	2,81	27,4	2,2	14,3	2,13	13,3	2,11	12,9	1,68	7,09	1,67	6,94	1,35	4,1	1,35	4,01	0,96	1,62
1000	3,87	63,1	2,87	28,6	2,24	14,9	2,18	13,8	2,16	13,5	1,72	7,39	1,7	7,22	1,39	4,27	1,38	4,18	0,98	1,69
1020	3,95	65,6	2,92	29,7	2,29	15,5	2,22	14,4	2,2	14	1,75	7,69	1,73	7,51	1,42	4,44	1,41	4,35	1	1,76
1040	4,02	68,2	2,98	30,9	2,33	16,2	2,26	14,9	2,24	14,6	1,78	7,99	1,77	7,81	1,45	4,61	1,44	4,52	1,02	1,83
1060	4,1	70,9	3,04	32,1	2,38	16,8	2,31	15,5	2,28	15,1	1,82	8,3	1,8	8,11	1,48	4,79	1,46	4,7	1,04	1,9
1080	4,18	73,6	3,1	33,3	2,42	17,4	2,35	16,1	2,33	15,7	1,85	8,62	1,84	8,42	1,5	4,98	1,49	4,87	1,06	1,97
1100	4,26	76,3	3,15	34,6	2,46	18,1	2,39	16,7	2,37	16,3	1,89	8,94	1,87	8,74	1,53	5,16	1,52	5,05	1,08	2,05
1150			3,3	37,8	2,58	19,7	2,5	18,3	2,48	17,8	1,97	9,77	1,96	9,55	1,6	5,64	1,59	5,53	1,13	2,24
1200			3,44	41,2	2,69	21,5	2,61	19,9	2,59	19,4	2,05	10,6	2,04	10,4	1,67	6,14	1,65	6,02	1,18	2,44
1250			3,58	44,7	2,8	23,3	2,71	21,6	2,69	21,1	2,14	11,5	2,13	11,3	1,74	6,66	1,73	6,53	1,22	2,64
1300			3,72	48,3	2,91	25,2	2,83	23,4	2,8	22,8	2,23	12,5	2,21	12,2	1,81	7,21	1,8	7,06	1,27	2,86
1350			3,87	52,1	3,03	27,2	2,94	25,2	2,91	24,6	2,32	13,5	2,3	13,2	1,88	7,77	1,87	7,62	1,32	3,08
1400			4,01	56	3,14	29,3	3,05	27,1	3,02	26,4	2,4	14,5	2,38	14,2	1,95	8,36	1,93	8,19	1,37	3,31
1450			4,16	60,1	3,25	31,4	3,16	29,1	3,12	28,3	2,49	15,5	2,47	15,2	2,02	8,97	2	8,79	1,42	3,56
1500			4,3	64,2	3,36	33,6	3,26	31,1	3,23	30,3	2,57	16,6	2,55	16,2	2,09	9,6	2,07	9,4	1,47	3,8
1550			4,44	68,7	3,47	35,9	3,37	33,2	3,34	32,4	2,66	17,7	2,64	17,3	2,16	10,2	2,14	10	1,52	4,06
1600			4,59	73,2	3,59	38,2	3,48	35,4	3,45	34,5	2,74	18,9	2,72	18,5	2,23	10,9	2,21	10,7	1,57	4,33
1650			4,73	77,8	3,7	40,7	3,59	37,6	3,56	36,7	2,83	20,1	2,81	19,7	2,3	11,6	2,28	11,4	1,62	4,6

Continuation Table 9.24.

$D_н \times s$ мм (1)	630×7		720×9		720×8		720×7		820×9		820×8		920×10		920×9		920×8	
G (2) кг/с	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²	(3) v м/сек	(4) Δh кгс/м²
740	0,72	0,91	0,55	0,46	0,55	0,45	0,55	0,44	0,42	0,23	0,42	0,22						
760	0,74	0,95	0,57	0,48	0,57	0,46	0,56	0,47	0,44	0,24	0,43	0,24						
780	0,76	1,01	0,58	0,51	0,58	0,5	0,58	0,49	0,45	0,25	0,45	0,25						
800	0,78	1,06	0,6	0,53	0,6	0,53	0,59	0,52	0,45	0,27	0,46	0,25						
820	0,8	1,12	0,61	0,56	0,61	0,55	0,61	0,55	0,47	0,28	0,47	0,28						
840	0,82	1,17	0,63	0,59	0,63	0,58	0,62	0,57	0,48	0,29	0,48	0,29						
860	0,84	1,23	0,64	0,62	0,64	0,61	0,64	0,6	0,49	0,31	0,49	0,3						
880	0,86	1,29	0,66	0,65	0,66	0,64	0,65	0,63	0,51	0,32	0,5	0,32						
900	0,88	1,35	0,67	0,68	0,67	0,67	0,67	0,66	0,52	0,34	0,51	0,33						
920	0,9	1,41	0,69	0,71	0,69	0,7	0,68	0,69	0,53	0,35	0,53	0,35						
940	0,92	1,47	0,7	0,74	0,7	0,73	0,7	0,71	0,54	0,37	0,54	0,36						
960	0,93	1,53	0,72	0,77	0,72	0,76	0,71	0,75	0,55	0,38	0,55	0,38						
980	0,95	1,6	0,73	0,8	0,73	0,79	0,73	0,78	0,56	0,4	0,56	0,39						
1000	0,97	1,66	0,75	0,84	0,75	0,82	0,74	0,81	0,57	0,42	0,57	0,41						
1020	0,99	1,73	0,76	0,87	0,76	0,86	0,76	0,84	0,59	0,43	0,58	0,43						
1040	1,01	1,8	0,78	0,9	0,78	0,89	0,77	0,88	0,6	0,45	0,59	0,44						
1060	1,03	1,87	0,79	0,94	0,79	0,93	0,79	0,91	0,61	0,47	0,61	0,46						
1080	1,05	1,94	0,81	0,98	0,8	0,96	0,8	0,95	0,62	0,48	0,62	0,48						
1100	1,07	2,01	0,82	1,01	0,82	1	0,82	0,98	0,63	0,5	0,63	0,5	0,5	0,27	0,5	0,27	0,5	0,27
1150	1,12	2,2	0,86	1,11	0,86	1,09	0,85	1,07	0,65	0,55	0,66	0,54	0,52	0,3	0,52	0,3	0,52	0,29
1200	1,17	2,39	0,9	1,2	0,89	1,19	0,89	1,17	0,69	0,6	0,69	0,59	0,55	0,33	0,54	0,32	0,54	0,32
1250	1,22	2,6	0,94	1,31	0,93	1,29	0,93	1,27	0,72	0,65	0,71	0,64	0,57	0,35	0,57	0,35	0,56	0,35
1300	1,27	2,81	0,97	1,41	0,97	1,39	0,96	1,37	0,75	0,7	0,74	0,69	0,59	0,38	0,59	0,38	0,59	0,37
1350	1,31	3,03	1,01	1,52	1,01	1,5	1	1,48	0,78	0,76	0,77	0,75	0,62	0,41	0,61	0,01	0,61	0,4
1400	1,36	3,26	1,05	1,64	1,04	1,61	1,04	1,59	0,8	0,81	0,8	0,8	0,64	0,44	0,64	0,44	0,63	0,43
1450	1,41	3,5	1,09	1,76	1,08	1,73	1,07	1,71	0,83	0,87	0,83	0,86	0,66	0,48	0,66	0,47	0,66	0,47
1500	1,46	3,74	1,12	1,88	1,12	1,85	1,11	1,83	0,86	0,94	0,86	0,92	0,68	0,51	0,68	0,5	0,68	0,5
1550	1,51	3,99	1,16	2,01	1,16	1,98	1,15	1,95	0,89	1	0,89	0,99	0,71	0,55	0,7	0,54	0,7	0,53
1600	1,56	4,26	1,2	2,14	1,19	2,11	1,19	2,08	0,92	1,06	0,91	1,05	0,73	0,58	0,73	0,57	0,72	0,57
1650	1,61	4,53	1,24	2,28	1,23	2,24	1,22	2,21	0,95	1,13	0,94	1,12	0,75	0,62	0,75	0,61	0,75	0,6

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Continuation Table 9.24.

(1) $D_н \times S$ мм	426×10		426×7		426×6		478×7		478×6		529×7		529×6		630×8		630×7		720×9		720×8	
(2) G в т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
1700	3,81	43,2	3,7	39,9	3,66	38,9	2,92	21,3	2,89	20,9	2,37	12,3	2,35	12,1	1,67	4,89	1,65	4,8	1,27	2,42	1,27	2,38
1750	3,92	45,7	3,81	42,3	3,77	41,3	3	22,6	2,98	22,1	2,44	13,1	2,42	12,8	1,71	5,18	1,7	5,09	1,31	2,56	1,3	2,52
1800	4,03	48,4	3,91	44,8	3,88	43,7	3,09	23,9	3,06	23,4	2,51	13,8	2,49	13,5	1,76	5,48	1,75	5,39	1,35	2,71	1,34	2,67
1850	4,15	51,1	4,03	47,3	3,99	46,1	3,17	25,3	3,15	24,7	2,58	14,6	2,56	14,3	1,81	5,79	1,8	5,69	1,39	2,86	1,38	2,82
1900	4,26	53,9	4,13	49,9	4,09	48,6	3,26	26,7	3,23	26,1	2,65	15,4	2,63	15,1	1,86	6,1	1,85	6	1,42	3,02	1,42	2,97
1950	4,37	56,8	4,24	52,6	4,2	51,2	3,35	28,1	3,32	27,5	2,72	16,2	2,69	15,9	1,91	6,43	1,9	6,32	1,46	3,18	1,45	3,13
2000	4,48	59,7	4,35	55,5	4,31	53,9	3,43	29,5	3,4	28,9	2,79	17,1	2,76	16,7	1,96	6,76	1,95	6,65	1,5	3,35	1,49	3,3
2100							3,6	32,6	3,57	31,8	2,92	18,8	2,9	18,4	2,06	7,46	2,04	7,33	1,57	3,69	1,57	3,63
2200							3,77	35,8	3,74	35	3,06	20,6	3,04	20,2	2,16	8,18	2,14	8,05	1,65	4,05	1,64	3,99
2300							3,95	39,1	3,91	38,2	3,2	22,6	3,18	22,1	2,25	8,95	2,24	8,79	1,72	4,42	1,71	4,35
2400							4,12	42,5	4,08	41,6	3,34	24,6	3,32	24,1	2,35	9,74	2,34	9,58	1,8	4,82	1,79	4,75
2500							4,29	46,2	4,25	45,1	3,48	26,7	3,45	26,1	2,45	10,6	2,43	10,4	1,87	5,23	1,86	5,15
2600							4,46	49,9	4,42	48,8	3,62	28,8	3,59	28,3	2,55	11,4	2,53	11,2	1,95	5,65	1,94	5,57
2700							4,63	53,9	4,59	52,6	3,76	31,1	3,73	30,5	2,65	12,3	2,63	12,1	2,02	6,1	2,01	6,01
2800							4,8	57,9	4,76	56,6	3,9	33,4	3,87	32,8	2,74	13,3	2,73	13	2,1	6,56	2,09	6,46
2900							4,98	62,1	4,93	60,7	4,01	35,9	4,01	35,1	2,84	14,2	2,82	14	2,17	7,05	2,16	6,93
3000							5,15	66,5	5,1	65	4,18	38,4	4,15	37,6	2,94	15,2	2,92	15	2,25	7,53	2,24	7,42
3100							5,32	71	5,27	69,4	4,32	41	4,28	40,2	3,04	16,3	3,02	16	2,32	8,01	2,31	7,92
3200							5,49	75,6	5,44	73,9	4,46	43,7	4,42	42,8	3,14	17,3	3,11	17	2,4	8,56	2,38	8,44
3300							5,66	80,4	5,61	78,6	4,9	46,4	4,56	45,5	3,23	18,4	3,21	18,1	2,47	9,11	2,46	8,97
3400							5,83	85,4	5,78	83,5	4,74	49,3	4,7	48,3	3,33	19,5	3,31	19,2	2,55	9,67	2,53	9,53
3500							6	90,6	5,95	88,5	4,87	52,3	4,84	51,2	3,43	20,7	3,41	20,4	2,62	10,2	2,61	10,1
3600							6,18	95,7	6,12	93,6	5,01	55,3	4,97	54,2	3,53	21,9	3,5	21,5	2,7	10,8	2,68	10,7
3700							6,35	101,1	6,29	98,9	5,15	58,4	5,11	57,2	3,63	23,2	3,6	22,8	2,77	11,5	2,76	11,3
3800									6,46	104,2	5,29	61,6	5,25	60,3	3,72	24,4	3,7	24	2,85	12,1	2,83	11,9
3900											5,43	64,9	5,39	63,6	3,82	25,7	3,8	25,3	2,92	12,7	2,91	12,5
4000											5,57	68,2	5,53	66,9	3,92	27,1	3,89	26,6	3	13,4	2,98	13,2
4200															4,11	29,8	4,09	29,3	3,15	14,8	3,13	14,5
4400															4,31	32,7	4,28	32,2	3,3	16,2	3,28	16
4600															4,51	35,8	4,48	35,2	3,45	17,7	3,43	17,4

Continuation Table 9.24.

(1) $D_н \times S$ мм	720×7		820×9		820×8		920×10		920×9		920×8		1020×11		1020×10		1020×8		1220×12		1220×9	
(2) G в т/ч	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м	(3) v в м/сек	(4) Δh в кгс/м² м
1700	1,36	2,35	0,98	1,2	0,97	1,19	0,78	0,66	0,77	0,65	0,77	0,64	0,63	0,38	0,63	0,38	0,62	0,37	0,44	0,15	0,43	0,14
1750	1,3	2,49	1	1,27	1	1,26	0,8	0,69	0,79	0,69	0,79	0,68	0,65	0,4	0,65	0,4	0,64	0,39	0,45	0,16	0,45	0,15
1800	1,33	2,63	1,03	1,35	1,03	1,34	0,82	0,74	0,82	0,73	0,81	0,72	0,67	0,43	0,66	0,42	0,66	0,41	0,46	0,17	0,46	0,16
1850	1,37	2,78	1,06	1,42	1,06	1,4	0,84	0,78	0,84	0,77	0,84	0,76	0,69	0,45	0,68	0,45	0,68	0,44	0,48	0,17	0,47	0,17
1900	1,41	2,93	1,09	1,5	1,09	1,48	0,87	0,82	0,86	0,81	0,86	0,8	0,7	0,48	0,7	0,47	0,7	0,46	0,49	0,18	0,49	0,18
1950	1,45	3,09	1,12	1,58	1,11	1,56	0,89	0,86	0,89	0,85	0,88	0,84	0,72	0,5	0,72	0,5	0,71	0,49	0,5	0,19	0,5	0,19
2000	1,48	3,25	1,15	1,66	1,14	1,64	0,91	0,91	0,91	0,9	0,9	0,89	0,74	0,53	0,74	0,52	0,73	0,51	0,52	0,2	0,51	0,2
2100	1,56	3,58	1,21	1,83	1,2	1,81	0,91	0,91	0,95	0,99	0,95	0,98	0,78	0,58	0,78	0,58	0,77	0,56	0,54	0,23	0,54	0,22
2200	1,63	3,93	1,26	2,01	1,25	1,99	0,96	1	1	1,09	0,99	1,07	0,82	0,64	0,81	0,63	0,81	0,62	0,57	0,25	0,56	0,24
2300	1,7	4,29	1,32	2,2	1,31	2,17	1	1,1	1,04	1,19	1,04	1,17	0,85	0,7	0,85	0,69	0,84	0,68	0,59	0,27	0,59	0,25
2400	1,78	4,68	1,38	2,39	1,37	2,36	1,05	1,2	1,09	1,29	1,08	1,28	0,89	0,76	0,89	0,75	0,88	0,74	0,62	0,29	0,61	0,29
2500	1,85	5,07	1,44	2,6	1,43	2,56	1,09	1,31	1,13	1,4	1,13	1,39	0,93	0,82	0,92	0,82	0,92	0,8	0,65	0,32	0,64	0,31
2600	1,93	5,49	1,49	2,81	1,49	2,77	1,14	1,42	1,18	1,52	1,18	1,5	0,96	0,89	0,96	0,88	0,95	0,86	0,67	0,35	0,66	0,34
2700	2	5,92	1,55	3,03	1,54	2,99	1,19	1,53	1,23	1,64	1,22	1,62	1	0,96	1	0,95	0,99	0,93	0,7	0,37	0,69	0,36
2800	2,07	6,36	1,61	3,26	1,6	3,22	1,23	1,65	1,27	1,76	1,27	1,74	1,04	1,03	1,03	1,02	1,03	1	0,72	0,4	0,72	0,39
2900	2,15	6,83	1,67	3,49	1,66	3,45	1,28	1,78	1,32	1,89	1,31	1,86	1,08	1,11	1,07	1,1	1,06	1,08	0,75	0,43	0,74	0,42
3000	2,22	7,31	1,72	3,74	1,71	3,69	1,32	1,91	1,36	2,02	1,36	2	1,12	1,19	1,11	1,18	1,1	1,15	0,77	0,46	0,77	0,45
3100	2,3	7,8	1,78	3,99	1,77	3,94	1,37	2,04	1,41	2,16	1,4	2,13	1,15	1,27	1,15	1,25	1,14	1,23	0,8	0,49	0,79	0,48
3200	2,37	8,31	1,84	4,26	1,83	4,2	1,41	2,18	1,45	2,3	1,45	2,27	1,19	1,35	1,18	1,34	1,17	1,31	0,83	0,52	0,82	0,51
3300	2,45	8,84	1,9	4,53	1,89	4,47	1,46	2,32	1,5	2,44	1,49	2,41	1,22	1,44	1,22	1,42	1,21	1,39	0,85	0,56	0,84	0,54
3400	2,52	9,38	1,95	4,8	1,94	4,74	1,5	2,47	1,54	2,59	1,54	2,56	1,26	1,53	1,26	1,51	1,25	1,48	0,88	0,59	0,87	0,58
3500	2,59	9,94	2	5,09	2	5,02	1,55	2,62	1,59	2,75	1,58	2,72	1,3	1,62	1,29	1,6	1,28	1,57	0,9	0,63	0,89	0,61
3600	2,67	10,5	2,07	5,39	2,06	5,32	1,6	2,78	1,63	2,91	1,63	2,87	1,34	1,71	1,33	1,69	1,32	1,66	0,93	0,66	0,92	0,65
3700	2,74	11,1	2,12	5,69	2,11	5,62	1,64	2,94	1,68	3,07	1,67	3,04	1,37	1,81	1,37	1,79	1,36	1,75	0,96	0,7	0,95	0,68
3800	2,82	11,7	2,18	6	2,17	5,92	1,69	3,11	1,73	3,24	1,72	3,2	1,41	1,91	1,4	1,89	1,39	1,85	0,98	0,74	0,97	0,72
3900	2,89	12,3	2,24	6,32	2,23	6,24	1,73	3,28	1,77	3,41	1,76	3,37	1,45	2,01	1,44	1,99	1,43	1,94	1,01	0,78	1	0,76
4000	2,96	13	2,3	6,65	2,29	6,56	1,78	3,45	1,82	3,59	1,81	3,55	1,48	2,11	1,48	2,09	1,47	2,05	1,03	0,82	1,02	0,8
4200	3,11	14,3	2,41	7,33	2,4	7,24	1,82	3,63	1,91	3,96	1,9	3,91	1,56	2,33	1,55	2,3	1,54	2,26	1,08	0,9	1,07	0,88
4400	3,26	15,7	2,53	8,04	2,51	7,94	1,92	4	2	4,34	1,99	4,29	1,63	2,55	1,63	2,53	1,61	2,48	1,14	0,99	1,12	0,96
4600	3,41	17,2	2,64	8,79	2,63	8,68	2,01	4,39	2,09	4,75	2,08	4,69	1,71	2,79	1,7	2,76	1,69	2,71	1,19	1,08	1,18	1,05

Key: (1). in mm. (2). G in t/h. (3). in m/s. (4). in kgf/m² m.

Page 160.

The coefficient of an increase in the loss of pressure on friction and speeds is determined from the formula

$$\varphi = \frac{958.4}{\gamma_{см}}, \qquad (9.45)$$

where 958.4 is the specific gravity/weight of the condensate by which are comprised the tables and nomograms for the calculation of forcing condensate pipings in kG/m³;

$\gamma_{см}$ — the specific gravity/weight of steam-water mixture in kG/m³.

Value φ can be determined according to Table 9.25.

The specific gravity/weight of steam-water mixture without taking into account of span vapor is determined from the formula

$$\gamma_{см} = \frac{\gamma' \gamma''}{x(\gamma' - \gamma'') + \gamma''} \ kg/m^3, \qquad (9.46)$$

where γ' is the specific gravity/weight of condensate at pressure P_2 in kg/m^3;

γ'' - the specific gravity/weight of the saturated steam at pressure P_2 in kg/m^3;

x - a quantity is the pair of the secondary effervescence, which is obtained with the effervescence of condensate as a result of a pressure drop from P_1 to P_2, in kg/kg;

P_1 - the pressure before the drainage controller in kg/cm^2, taken on pressure pair in the local system of user or on pressure in steam line;

P_2 - pressure at the end of the calculated section of the pipeline of steam-water mixture (in the expansion tank, receiver tank of condensate, at the branch point of pipelines) in kg/cm^2; with the free drain of condensate pressure P_2 takes as equal atmospheric.

A quantity the pair of secondary effervescence is

determined from the formula

$$x = \frac{i'_1 - i'_2}{r_2} \text{ kg/kg;} \qquad (9.47)$$

values x determine according to table 9.26;

i'_1, i'_2 - the enthalpy of condensate respectively at pressures P_1 and P_2 (enthalpy of water on the line of saturation) in kcal/kg;

r_2 - heat of vaporization at pressure P_2 in kcal/kg.

Values $\gamma_{см}$ are determined from Table 9.27.

If we conditionally accept specific loss of pressure on friction in forcing condensate piping and in the condensate piping, which transports steam-water mixture, identical, the diameter of the latter it is possible to determine by the formula

$$D_{в.см} = D_в \sqrt[5.25]{\frac{958.4}{\gamma_{см}}} \text{ мм.} \qquad (9.48)$$

where $D_в$ – the bore of condensate piping into mm, determined by tables and nomograms for hydraulic design of forcing condensate pipings with γ = 958.4 kg/m³ and k = 1 mm.

Specific losses of pressure on friction during hydraulic design of composite condensate pipings are determined according to the available pressure differential, determined according to formula (9.35), but at the speed of steam-water mixture not more given in table 9.18 for the saturated steam. The available loss of pressure on friction and local resistance is determined from the formula

$$H^p = \left[P_1' - P_2 - 0.1\left(h_r^к - h_r^н\right)\right] 10^4 \quad \text{kgf/m}^2, \qquad 9.49$$

where p'_1 - pressure after steam trap in kg/cm² are determined by the value of pressure before steam trap and the loss of pressure in vessel itself, depending on the construction of vessel;

$h_r^к, h_r^н$ - the geodetic marks of end and beginning of the designed section of pipeline in m.

Pressure after steam trap is determined from the formula

$$P_1' = a(P_1 - 1) + 1 \quad \text{kg/cm}^2, \qquad (9.50)$$

where a is the coefficient, which considers loss of pressure in steam trap; it is possible to accept depending on pressure tentatively a = 0.5-0.7.

For hydraulic design of composite condensate pipings, they compose design diagram (see Fig. 9.15).

First of all is performed the calculation of the basic calculated main line for which by formula (9.35) is obtained the smallest available loss of pressure on friction; branches from basic main line are designed for their available specific losses of pressure on friction, determined on the difference of pressures in the units of branches and in users.

Hydraulic design of composite condensate pipings is performed in form, given in Table 9.28.

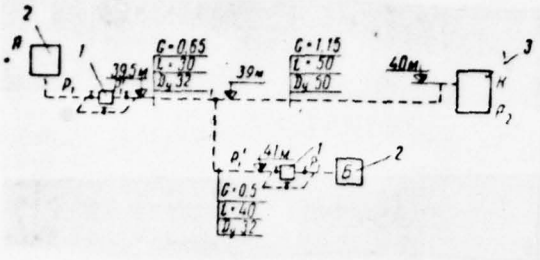


Fig. 9.15. The design diagram of composite condensate **pipings.** G - the consumption of condensate in t/h; *l* - the length of calculated section in m; D_y - the internal diameter of pipeline in mm; 1 - steam trap; 2 - heat exchanger; 3 - condensate tank.

9.7. Graphs of pressures.

The graphs of pressures develop/process for water thermal grid/networks in state of rest of heat carrier (hydrostatic conditions/mode) and during the steady motion of heat carrier (hydrodynamic conditions/mode).

Graphs develop/process for a basic calculated main line and characteristic branches, but with several main lines of one heat source - for each of the main lines, combining them on one drawing.

The scale of the graph of pressures and the scale of the airfoil/profile of the earth/ground on which are constructed the graphs, accept, as a rule, horizontal 1:10000 to 1:20000, vertical - 1:1000 to 1:2000. On this same scale on the airfoil/profile of the earth/ground, they

show the height/altitude of the characteristic buildings, connected up thermal grid/networks.

Conditionally it is assumed that the mark of the pipe laying, installation of pumps and heaters in the first deck of buildings coincides with the mark of the earth/ground. The higher position of water in local system takes as equal to the height/altitude of building.

If in separate users heaters are arrange/located in the basements of buildings, the mark of their installation accepts equal to the mark of the sex/floor of basement, which also will be applied to airfoil/profile.

Scheduling begins with hydrostatic conditions/mode for the conditions of the filling of system with water with temperature to 100°C at the direct of the diagrams of the connection of the local systems of all users of heat.

A possible increase in the static pressure in system because of the effervescence of water with the temperature above 100°C at emergency shutdown of system is not considered. During scheduling of pressures for the static behavior:

define the need for the division of system independent variables with the statics of zone on the basis of the conditions of the direct connection of all local systems for users to thermal grid/network;

in the case of the division of system into zones is defined the place of arrangement/position on thermal network of separating catches (units of crosscut);

is defined pressure of makeup pumps both in the heat source and in the units of crosscut;

they more precisely formulate the diagram of the connection of the local systems of separate users.

Table 9.25. Values of coefficient φ.

(1) Начальное давление P_1 в кгс/см²	(2) φ при конечном давлении P_2 в кгс/см²										
	1	1,2	1,4	1,6	1,8	2	3	4	5	6	7
1,2	16,8										
1,5	36,8	18,2	5,7								
2	64,7	41,5	25,9	15	7						
2,5	87	60,5	42,4	29,6	20,1	13					
3	106,5	76,5	56,4	42	31,4	23,2					
3,5	129	90,4	69	53,2	41	31,4	5,7				
4	137	103	79,8	62,6	49,9	39,9	12,8				
5	162	126	98,8	79,7	65,2	54,5	22,2	8,7			
8	223	174	143	119	100	85,5	44	25,7	14,9	8,4	4,1
10	252	199,5	165	137	117	102	55	34,6	21,8	14,2	9,5
15	309	252	208	177,5	154,5	133	78	51,2	35,6	26,2	19,8
20	355	290	246	208	181	157	95,3	64,7	47	35,8	28,2
25	416	319	274	234	204	181	109	75,5	56	43,3	34,8
30	435	354	299	252	223	195,5	121	85,5	64,3	50,4	40,3
35	479	383	320	274	240	208	137	94	70,5	55,7	46

Key: (1). Initial pressure P_1 in kg/cm². (2). φ with stagnation pressure P_2 in kg/cm².

page 162.

Table 9.26. A quantity is the pair of the secondary effervescence x in kg/kg.

Начальное давление P_1 в кгс/см² (1)	(2) x при конечном давлении P_2 в кгс/см²										
	1	1,2	1,4	1,6	1,8	2	3	4	5	6	7
1,2	0,01										
1,5	0,022	0,012	0,004								
2	0,039	0,029	0,021	0,013	0,006						
2,5	0,052	0,043	0,034	0,027	0,02	0,014					
3	0,064	0,054	0,046	0,039	0,032	0,026					
3,5	0,077	0,064	0,056	0,049	0,042	0,036	0,01				
4	0,083	0,073	0,065	0,058	0,051	0,045	0,02				
5	0,098	0,089	0,081	0,074	0,067	0,061	0,036	0,017			
8	0,134	0,125	0,117	0,11	0,104	0,098	0,073	0,054	0,038	0,024	0,012
10	0,152	0,143	0,136	0,129	0,122	0,117	0,093	0,074	0,058	0,044	0,032
15	0,188	0,18	0,172	0,165	0,161	0,154	0,13	0,112	0,096	0,083	0,071
20	0,216	0,208	0,205	0,194	0,188	0,182	0,159	0,122	0,127	0,113	0,102
25	0,252	0,232	0,225	0,221	0,212	0,205	0,184	0,147	0,152	0,139	0,127
30	0,26	0,252	0,245	0,239	0,233	0,288	0,205	0,188	0,174	0,161	0,15
35	0,279	0,271	0,262	0,26	0,252	0,238	0,225	0,208	0,193	0,181	0,17

Key: (1). Initial pressure P_1 in kg/cm². (2). x at stagnation pressure P_2 in kg/cm².

Table 9.27. The specific gravity/weight of steam-water mixture $\gamma_{см}$ in kG/m^3.

(1) Начальное давление P_1 в кгс/см²	(2) $\gamma_{см}$ при конечном давлении P_2 в кгс/см²										
	1	1,2	1,4	1,6	1,8	2	3	4	5	6	7
1,2	57										
1,5	26	52,5	169								
2	14,8	23,1	37	63,9	136,5						
2,5	11	15,8	22,6	32,3	47,6	73,5					
3	9	12,5	17	22,8	30,5	41,3					
3,5	7,4	10,6	13,9	18	23,3	30,5	168				
4	7	9,3	12	15,3	19,2	24	74,5				
5	5,9	7,6	9,7	12	14,7	17,7	43	110,5			
8	4,3	5,5	6,7	8,1	9,6	11,2	21,8	37,3	64,3	114	232,4
10	3,8	4,8	5,8	7	8,2	9,4	17,4	27,7	43,8	67,3	101,5
15	3,1	3,8	4,6	5,4	6,2	7,2	12,3	18,7	26,9	36,6	48,3
20	2,7	3,3	3,9	4,6	5,3	6,1	10,1	14,8	20,4	26,8	34
25	2,3	3	3,5	4,1	4,7	5,3	8,8	12,7	17,1	22,1	27,5
30	2,2	2,7	3,2	3,8	4,3	4,9	7,9	11,2	14,9	19	23,4
35	2	2,5	3	3,5	4	4,6	7	10,2	13,6	17,2	20,4

Key: (1). the initial pressure P_1 in kg/cm^2. (2). at stagnation pressure P_2 in kg/cm^2.

Page 163.

Static pressure on graph is characterized by the horizontal line, drawn on the mark of the highest position of water. The difference between the mark of this line and the mark of the unknown point of thermal grid/network, preheating installation of the source of heat, local system of building determines overpressure (hydrostatic) at this

point in m water column. If pressure by any point of system does not exceed permissible ultimate strength, thermal grid/network do not divide into are separate zones.

Table 9.31 gives ultimate pressures for some types of the equipment of heat sources and local systems of heating, ventilation and hot water supply of the connected buildings.

The small permissible pressure, as a rule, have the local heating systems of the buildings to which they are oriented during the analysis of graph for static behavior. For local heating systems number system by cast iron radiators it is possible to allow/assume pressure to 60 m by water column.

One should to this limit lead the local systems of the separate old buildings, arrange/located in areas of new building, with conducting the appropriate hydraulic tests also if necessary to replace separate instruments.

If pressure above 60 m of water. st. is obtained only of several separate buildings, their local systems connect on independent circuit. If this high pressure it is noted for a whole area, thermal network they divide into separate

zones. In certain cases the highest mark of the local system, determining the level of static pressure, has one or several buildings. Their connection according to independent diagram can sharply lower the line of static pressure.

Table 9.28. Form of table and an example of hydraulic design of the pipelines of steam-water mixture.

(1) № участков	(2) Расход пароводяной смеси в м/ч	(3) Характеристика трубы: (4) условный проход в мм	(5) наружный диаметр в мм × толщина стенки трубы в мм	(6) Разность геодезических отметок в конце и начале участка $\pm(h_1^к - h_1^н)$ в м	(7) Давление перед конденсационным горшком P_1 в кг/см²	(8) Давление в начале участка конденсатопровода P_1 в кг/см²	(9) Давление в конце участка конденсатопровода или в конденсатном баке или расширительном баке P_2 в кг/см²	(10) Коэффициент φ	(11) Длина участка трубопровода в м: по плану l	эквивалентная местным сопротивлениям $l_э$	приведенная $l_{пр} = l + l_э$	(12) Конденсат при $t =$ =95,8 кгс см²: скорость v в м/сек	удельная потеря давления Δh в кгс/м	(13) Пароводяная смесь при tсм: (20) скорость $v_{см} = \varphi v$ в м/сек	(21) потеря давления: удельная $\Delta h_{см} =$ $= \varphi \Delta h$ кгс/м²	на участке $\Delta H_{см} =$ $= \Delta h_{см} l_{пр}$ кгс/м²	(14) Суммарная потеря давления от конденсатоотводчика $H = \Sigma \Delta H_{см}$ × 10^{-4} в кгс/см²	Примечания
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
(25) Основная расчетная магистраль																		
A–1	0,95	32	38×2,5	−0,5	2,5	2,05	1,8	20,1	30	6	36	0,22	4,12	4,43	83	2980	0,3	
1–K	1,15	50	57×3,5	+1	2,5	1,8	1,2	60,5	50	10	60	0,17	1,37	10,3	83	4980	0,8	
(26) Ответвление																		
Б–1	0,5	32	38×2,5	−2	2,5	2,05	1,8	20,1	40	8	48	0,17	2,44	3,42	49	2350	0,24	

Key: (1). sections. (2). Consumption of steam-water mixture in m/h. (3). Characteristic of tube. (4). the internal diameter in mm. (5). outside diameter in mm x the wall thickness of tube (5a). in mm. (6). Difference in the geodetic marks at the end and beginning of section in m. (7). Pressure before steam trap P_1 in kg/cm². (8). Pressure in the beginning of the section of condensate piping P_1 in kg/cm². (9). Pressure at the end of the section of condensate piping or in condensate tank or expansion tank P_2 in kg/cm². (10). Coefficient φ. (11). the length of the section of pipeline in m. (12). Condensate

with γ = 958.4 kgf/cm³. (13). Steam-water mixture when (14). Total loss of pressure from drainage controller 10 ⁴ in kg/cm². (15). according to the plan. (16). equivalent to local resistance. (17). given. (18). speed v in m/s. (19). specific loss of pressure Δ h in kg/m²m. (20). the speed (20a). in m/s. (21). loss of pressure. (22). specific (22a). = ϕ = Δh in kg/m²m. (23). on section (23a). in kgf/m². (24). Note. (25). Basic calculated main line. (26). Branch.

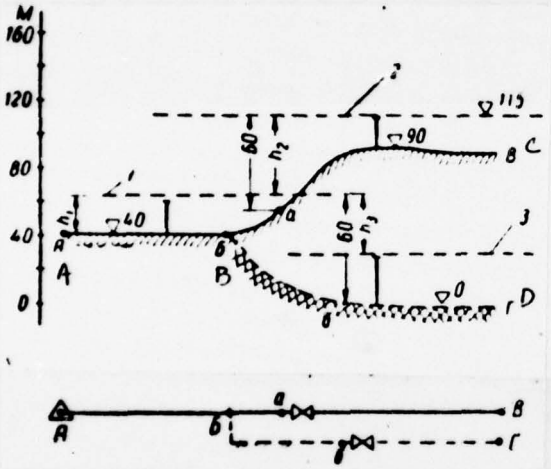


Fig. 9.16. Graph of pressures for the static behavior of system 1 - line of the static pressure of the first zone; 2 - the same, the second zone; 3 - the same, the third zone; h_1 - pressure of makeup pumps of heat source in m; h_2 - pressure of makeup pumps for the second zone in m; h_3 - pressure adjustment of additional feeding for the third zone in m; A - heat source; B - unit of branch; C

and D - final users.

Page 164.

Figures 9.16 shows the exemplary/approximate graph of pressures for the static behavior of system with complex relief of locality.

Large difference in the marks of the earth/ground will lead to the need for the division of system into three independent zones.

Band edges can be changed within considerable limits depending on the taken static pressure in the first zone.

In each specific case of band edge, one should accept being oriented toward the greatest coverage/scope of the users of the thermal grid/network of the first zone, which adjoins the heat and power plant.

The graph of pressures for hydrodynamic conditions/mode they develop/process for the conditions of steady motion of water in the pipelines of thermal network at calculated

consumption and the highest calculated temperature of water. The lines of the graphs of pressures are the locus upper ends of the cuts, which express the piezometric heads of the isolated points of thermal grid/network.

Piezometric head is that part of the complete hydrodynamic pressure, which is utilized to form hydrodynamic pressure. Complete pressure is counted off from the same conditional level from which is counted off geodetic height/altitude. Piezometric head determines the overpressure of water at the particular point.

During scheduling of pressures for the hydrodynamic conditions/mode:

are determined need for installation on the thermal grid/network of booster pumps, place of their arrangement/position and pressures;

is checked the need for installation on thermal network of pressure regulators, are determined the place of their arrangement/position and ranges of adjustment;

they more precisely formulate the head of network pumps

taking into account installation on the thermal grid/network of booster pumps and regulators of pressure;

is checked pressure of makeup pumps of heat source, selected during the development of static behavior, and is determined the need for pressure adjustment of additional feeding;

are determined the available pressures in the units of branching and during the input/introduction of thermal grid/network into central thermal point/items and the point/items of separate buildings.

Pressure at any point of system during hydrodynamic conditions/mode must provide the filling of system with water, prevent the effervescence of water and not to exceed the permissible strength of equipment of heating installations, pipelines of thermal network and local systems of the connected buildings. These conditions are accepted during the development of graphs and pressures both at the calculated consumption and the calculated temperature of water and during deviations from calculated, the possible in this system.

The pressure, which prevents the effervescence of water must be not less than the pressure of the dry saturated steam at saturation temperature and approximately with sufficient for practical calculations accuracy/precision it can be accepted according to as the datum of table 9.29.

Por hot-waters boiler additionally are considered the possibility of the local effervescence of water in pipes of the surface of heating and small pressure, preventing effervescence of water, accepts at saturation temperature, which exceeds the calculated by 30°C. At the entry into boiler pressure, must be higher by the value of hydraulic losses of pressure in boiler at the greatest calculated consumptio of water.

The approximately small pressure of water on of the entry into boiler can be accepted according to Table 9.30.

Great pressure for the linear part of the thermal grid/network is accepted depending on the type of the used tubes and fittings. Por local systems this pressure is accepted according to the corresponding projects depending on the types of heaters.

For the preheaters of network water and pumps great pressure is accepted according to technical specifications for their supply.

The value of the greatest pressure of water for some types of the equipment of the sources of heat and local systems is given in table 9.31.

Table 9.29.

(1) Расчетная температура воды в °С	(2) Давление в м вод. ст.
(3) До 110	5
120	10
130	20
140	30
150	40
160	55
170	72
180	93

Key: (1). The calculated temperature of water in °C. (2). Pressure in m water column. (3). To.

Table 9.30.

(1) Расчетная температура воды в °С в тепловой сети	(2) Давление в м вод. ст.
110	40
120	50
130	60
140	87
150	108
160	135
170	165
180	210

Key: (1). The calculated temperature of water in °C in thermal grid/network. (2). Pressure in m water column.

Table 9.31. 473

(1) Оборудование	(2) Наибольшее давление воды в м вод. ст.
(3) Подогреватели сетевой воды типов БО и БП Саратовского машиностроительного завода	140
(4) Пароводяные подогреватели по МВН Оргэнергостроя	100
(5) Водоводяные подогреватели по МВН Оргэнергостроя	100
(6) Водогрейные стальные котлы Бийского завода производительностью 50, 100 и 180 Гкал/ч	250
(7) Водогрейные стальные котлы Дорогобужского завода производительностью 12, 25, 50 Гкал/ч	150
(8) Чугунные водогрейные котлы	60
(9) Местные системы присоединяемых зданий	
(10) системы отопления и вентиляции с чугунными радиаторами	60
(11) то же, с бетонными панелями со змеевиками из труб	80
(12) то же, с бетонными беструбными панелями	40
(13) то же, с конвекторными приборами	90
(14) системы вентиляции промышленных зданий с калориферами по ГОСТ 7201-62	80
(15) системы горячего водоснабжения при их независимом присоединении через водяные подогреватели	100
(16) то же, из стальных труб при их непосредственном присоединении (открытая система)	80
(17) то же, при применении пластмассовых труб	40

Key: (1). Equipment. (2). Great pressure of water in m water column. (3). Preheaters of network water of the type BO and BP of the Saratov Machine Building Plant. (4). Steam-water preheaters of MVN of Orgenergostroy. (5). Water-to-water preheaters on MVN of Orgenergostroy. (6). Water-heating steel boilers of Biyskiy plant by productivity 50, 100, and 180 gcal/h. (7). Water-heating steel boilers of Dorogobuzhskiy plant with productivity of 12, 25, 50 gcal/h. (8). Cast iron hot-waters boiler. (9). Local systems of the connected buildings. (10). the heating system and ventilation with cast iron radiators. (11). the same, with concrete panels with coils from tubes. (12). the same, with

concrete pipeless panels. (13). the same, with convector instruments. (14). the ventilation system of industrial buildings with heaters according to GOST 7201-62. (15). the system of hot water supply during their independent connection through water preheaters. (16). the same, from steel tubes during their direct connection (open system). (17). the same, during the application/use of plastic tubes,

Page 165.

The line of the graph of pressures in supply pipeline must during the calculated and other conditions/modes be placed higher than the line, which connects upper ends of the cuts which express the overpressures, which prevent the effervescence of water (table 9.29 and 9.30) at the points of the highest position of water in thermal network, in local systems, in the preheaters of network water or in hot-waters boiler.

This conditional boundary line unlike the horizontal line of static pressure follows geodetic marks of the position of water in system.

At the same time the line of the graph of pressures in delivery pipe and the line of the graph of pressures in return line must not create a pressure at the isolated points of system, which exceed the permissible in condition of strengths of its units, which determines the higher position of the lines of graph.

The gradient/draft of the lines of the graph of pressures, which characterizes loss of pressure in pipelines is accepted for each section according to hydraulic design of the pipelines of thermal grid/network.

With insignificant difference in specific losses of pressure on friction on the individual sections of thermal grid/network or during the approximate estimate of hydrodynamic conditions/mode it is possible during graphing of pressures the gradient/draft of lines to accept according to the complete value of loss of pressure in calculated main line from heat source tto final user.

By the appropriate selection of pressures of network and makeup pumps and by arrangement/position on thermal network if necessary for booster pumps or regulators for

local decompression is determined the optimum position of the pressure lines of graph.

In comparison with the conditions/mode of system in the work only of network pumps of heat source, the booster pumps on the delivery pipe of thermal grid/network make it possible to lower the pressure of water in the preheating installation of heat source and in the delivery pipe between urce of heat and booster pump.

Booster pumps on return line of thermal network make it possible to lower pressure for the preheating installation of heat source, also, in entire thermal e, with the exception of the section of return line between sources of heat and booster pump.

In both cases the head of network pumps descends to value of head used for booster pumps.

For the existing thermal grid/networks the booster pumps, incresing the available pressure, is raised throughput capacity.

Installation on individual sections on feeding or return

lines of thermal network of additional resistance - pressure regulators, also makes it possible to lower pressure in thermal grid/network after this regulator (on the course of water).

Are examined below some characteristic examples of the graphs of the pressures (piezometers) of two-funnelled water thermal grid/network.

Specific losses of pressure are conditionally accepted differing by entire length of calculated main line.

Figures 9.17 shows the graph of pressures for the thermal grid/network of residential area with even area relief and small extent of grid/network. Are considered two cases - at the height/altitude of the connected buildings to 20 m and to 40 m.

In the first case the pressure of makeup pump, selected during static behavior from the conditions of filling of system in cold state equal to 20 m of water st., can remain without change and during hydrodynamic conditions/mode, which provides the simplest schematic of feed device.

In the second case the pressure of makeup pump, selected during static behavior equal to 40 m of odes st. during hydrodynamic conditions/mode must be lowered to 20-30 m of water, since during its maintenance at previous pressure level of water in the removed users will exceed the permissible limits.

In this case, the pressure in return line in area, which adjoins the heat source, is obtained below static, i.e., is lower than the height/altitude of the local systems of the connected buildings.

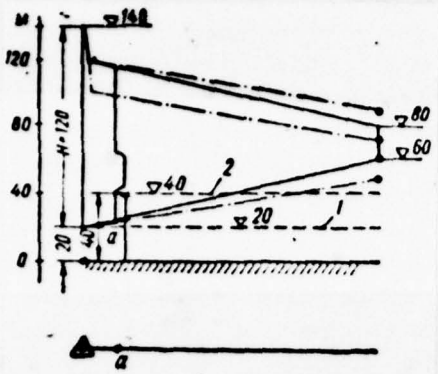


Fig. 9.17. Graph of pressures in thermal network with even relief of earth/ground and small extent of main line 1 - line of static pressure with arrangement in area of 4-5-graduated buildings; 2 - line of static pressure with location in area of buildings by height/altitude 40 m; ~~вст~~ а - place of installation on branch of valve of backwater; H - head of network pump in m.

Page 166.

For providing the work of the local systems of this company of buildings on return line of the introduction of thermal grid/network into each building or for the group of buildings are establish/installed the automatic valve-regulators of backwater, which maintain constant **pressure to themselves, providing at all conditions/modes**

filling with water of the local systems of the connected buildings.

Figures 9.18 shows the graph of pressures with even area relief, but with the large extent of calculated main line (on the order of 10-12 km).

The necessary conditions in system provide in this case the booster pumps, establish/installed on reverse/inverse and delivery pipes.

Figures 9.19 shows the graph of pressures for thermal network of small extent with the design chart of the temperatures by 150-70°C and nonelevator direct connection of local systems at the height/altitude of buildings 20 m.

Pressure of makeup pumps during the circulation of water in system must be higher than during static behavior, since will not be otherwise provided boiling of water with a temperature of 150°C in peak of local systems. However, the pressure of additional feeding in this case can prove to be that which is not admitted according to the conditions of the strength of network pump. In this case it is possible to leave pressure of makeup pumps equal to 20 m

of water, to increase the head of network pumps from 35 to 65 m of water and to provide automatic decompression in return line by special regulator wof constant pressure after itself.

Figures 9.20 shows the graph of pressures with depressed from heat source area relief.

Pressure of makeup pumps during the circulation of water in system in this case, as a rule, is selected smallest. Place of arrangement/position and pressure of booster pumps are determined on condition so that in the users, located on the lowest marks, would be supported pressure of not more than 60 m water column.

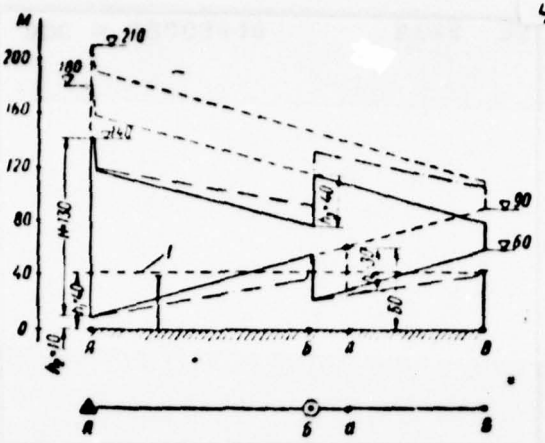


Fig. 9.18.

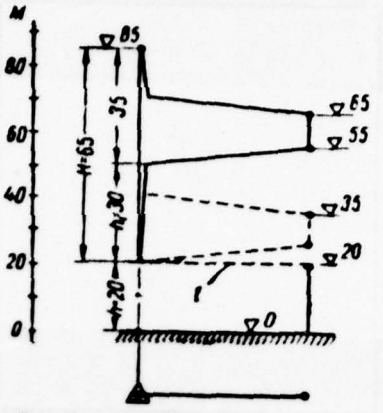


Fig. 9.19.

Fig. 9.18. Graph of pressures in thermal grid/network of large extent A - heat source; B - place of arrangement/position of booster pumps; a is possible place of arrangement/position of booster pump on return line; C is final user; 1 - line of static pressure; H - head of network pump in m; h_1 is pressure of makeup pump of heat source in m; h_2 is pressure of additional feeding during circulation of water in system; h_3 is pressure of booster pump on that which feeds in m; h_4 is pressure of booster pump on reverse/inverse in m.

Fig. 9.19. Graph of pressures in thermal grid/network of small extent and in work of local systems of buildings on superheated water 1 - line of static pressure; H - head of network pump in m; h - pressure of makeup pump in m;

h_1 is local decompression on return line in m.

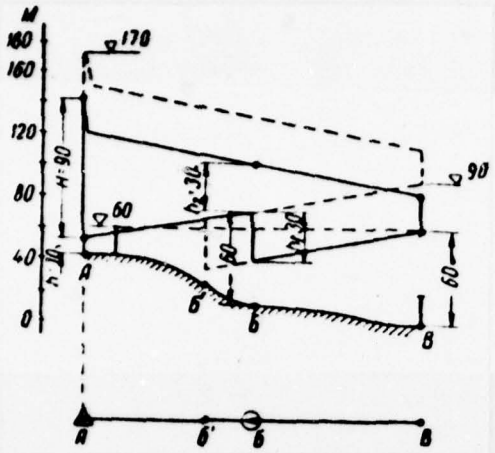


Fig. 9.20. The graph of pressures in thermal network with the depressed from heat source relief of the earth/ground

A - heat source; B are B' the zone of possible arrangement/position of the substation of pumping; H - pressure of network of pump in m; h - pressure of makeup pump in m; h_1 is pressure of booster pump in m; h_2 is the available pressure before booster pump in m.

Page 167.

Figures 9.21 shows the graph of pressures for thermal network with dropping relief of locality and with transit main between the source of heat and users. In this ~~sch~~ system of the ~~the~~ functions of network and booster pumps are combined. The

circulation of water provides one group of the pumps, arrange/located not of heat source, but on the route of thermal grid/network.

Makeup pumps are arrange/located at heat source. Pressure of makeup pumps is taken in this case of such, in order to avoid the effervescence of water during the circulation of water with calculated temperature. Pressure in delivery pipe on finite segments of main line is lower than static; however, this will not lead to the effervescence of water in pipelines at calculated temperature of 150°C.

Figures 9.22 shows the graph of pressures with raised area relief from heat source to users. With the calculated consumption of water, the position of the lines of graph provides everything necessary requirements. during a reduction/descent in the consumption of water necessary to additionally regulate pressure in return line on the collector/receptacle of heat source or in any of the units of thermal network.

In the case in question it is advisable to regulate pressure in node B of thermal network.

Figures 9.23 shows the graph of pressures with the complex relief of the earth/ground in thermal area.

In the multiple operation of several heat sources, is constructed the combined graph of pressures for the thermal grid/networks of all sources. To construct the combined graph they begin with the graph of basic, largest heat source in its work in their thermal area.

The obtained on this graph marks of piezometric heads and the available pressures in the units of the contiguity of the thermal grid/networks of other sources are accepted as the initial for graphing of the pressures of the thermal grid/networks of these sources in their joint operation.

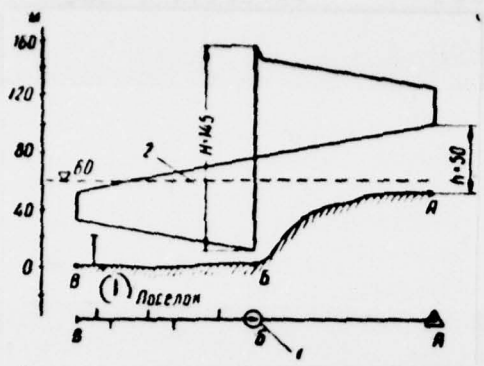


Fig. 9.21.

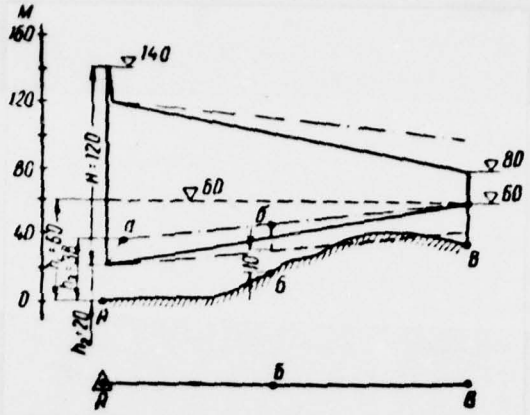


Fig. 9.22.

Fig. 9.21. Graph of pressures in thermal grid/network with depressed from heat source relief of earth/ground and transit main line on main section A - heat source; B - place of arrangement/position of network pumps; C is final user; H - head of network pump; h - pressure of makeup pump of heat source; 1 - network pump; 2 - line of static pressure.

Key: (1). Settlement.

Fig. 9.22. Graph of pressures in thermal network with raised from heat source relief of earth/ground A - heat source; C is final user; B - site of installation of control instrument; H - head of network pump; h_1 is pressure of makeup pump; h_2 is pressure of additional

feeding during circulation of water in system; h_3 is pressure of additional feeding during decrease in consumptic of water in system (version of regulation).

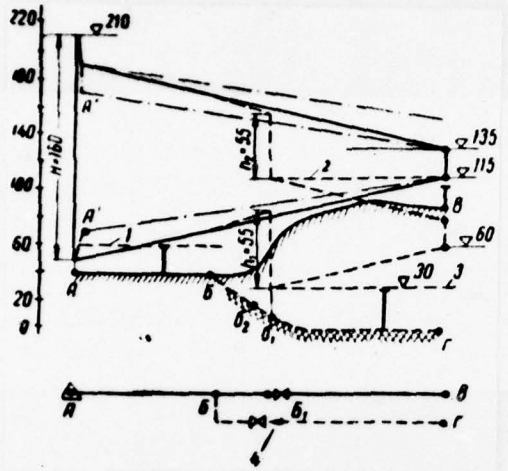


Fig. 9.23. The graph of pressures in thermal grid/network with the complex relief of the earth/ground A - heat source; B - the unit of branch; C and D - final users; B_1 and B_2 - the zone of the possible arrangement/position of booster pump; H - the head of network pump in m; h_1 is pressure of booster pump in m; h is a value of local decompression in the delivery pipe of branch in m; 1, 2 and 3 - the line of static pressure in the first, second and third zones; 4 - booster pumps on return line of branch.

Page 168.

Examples examined above make it possible to draw some practical conclusions which can facilitate scheduling:

1. The graphs of pressures for hydrostatic and hydrodynamic conditions/modes are considered separately, since both conditions/modes characterize the different in time and conditions of work state of system and solve different problems.

2. Pressure line, which prevents effervescence of water with calculated temperature at hydrodynamic conditions/mode, it follows for marks of position of water in system and with complex area relief can intersect with horizontal line of static pressure, which reflects filling of system with cold water.

3. Installation on feeding or reverse pipelines of booster pumps does not predetermine division of grid/network into independent variables with statics of zone, just as not in all cases of division of network with statics into zones appears need for setting up of booster pumps during circulation of water for system.

4. Pressure of makeup pumps, accepted from conditions of filling of system in cold state, one should ~~compulsorily~~ without fail check during hydrodynamic conditions/mode, since it can prove to be either insufficient or excessive for hydrodynamic conditions/mode.

5. Head of network pumps, accepted by basis of hydraulic designs as sum of losses of pressure with calculated consumption of water in preheating setting up, in pipelines of thermal grid/network (on calculated main line) and in local system of most removed user, it is necessary to check on curve/graph of pressures during hydrodynamic conditions/mode, since it can decrease established/installed booster pumps and increase established/installed in thermal grid/network pressure regulators.

Chapter 10

STRESS ANALYSIS OF PIPELINES AND FOR THE COMPENSATION FOR THERMAL ELONGATIONS.

10.1. Calculation of the pipelines of thermal grid/networks for strength.

The basic task of the stress analysis of pipelines is determination or testing the thicknesses of the walls of tubes, flight/spans between movable supports and the permissible compensating voltage/stresses.

Calculation for strenght of the pipelines of thermal grid/networks, as subordinate to Gosgorthkhnadvor on to 2, 3 and 4-o1 categories, is produced in accordance with p. 38 of the "rules of device and safe operation of the pipelines of vapor and hot water", on the "norms of the

calculation of the cell/elements of steam boilers for the strength" of TsKTI, publ. 1957 and "additions to the norms of the calculation of the cell/elements of steam boilers for the strength" of TsKTI, accepted by Gosgortekhnadzor into 1958.

For main-line gas pipes, oil pipelines and petroleum product lines, is applied at present the method of the stress analysis of tubes, given in chapter SNiP II-d.10-62, that considers the specific character of work conditions of these pipelines.

During the calculation of pipelines for strength, consider the following basic loads: the internal pressure of heat carrier, the dead weight of pipelines, load due to wind (with above-grade packing) and forces, which appear during the thermal elongations of pipelines. To the latter they are related: the force of elastic deformation and the bending moments of flexible compensators, including the angles of rotation, used for compensation; force of friction in movable supports with above-grade packing and packing in channels; the force of friction in gasket compensators.

During the calculation of the pipelines of thermal

grid/networks for strength, is provided for the complete utilization of permissible stress from the given above load because of the redistribution of stresses from these loads between themselves.

The consequence of the redistribution of stresses from the different form of loads is the possibility of an increase in the flight/spans between movable supports, decreases in the flights of flexible compensators or length of balance arms (for the sections of auto/self-compensation) with the insufficient utilization of allowable stress from internal pressure.

The calculation of pipeline is performed to the working order by which they accept:

a) internal pressure of heat carrier - equal to the greatest operating pressure taking into account a possible increase in it during changes in the conditions/mode of the work of equipment (turbines, pumps), and for water grid/networks (and condensate pipings) also taking into account the mark of the position of pipelines. For feeding and return lines of thermal grid/networks, it is allow/assumed to take the different value of operating

pressure in accordance with the real hydraulic conditions/mode of system, but is not less than 10 kg/cm²;

b) the temperature of the wall of tube [to equal maximally possible temperature of heat carrier; for steam lines - according to the temperature pair on the collector/receptacle of heat source taking into account oscillation/vibrations in the temperature at the different, conditions/modes of the work of equipment (turbines, boilers); for condensate pipings - on the temperature of condensate after condensate branches or condensate pumps; for the delivery pipe of two-funnelled water grid/network - according to the highest calculated temperature on the collector/receptacle of source of heat (taking into account an increase in the temperature by the heat losses in the thermal grid/network), while for return line - according to the highest calculated temperature of water on the curve/graph of temperatures taking into account the temperature, taken at time of heat tests of thermal grid/network (but it is not less than 100°C);

c) calculated weight is equal to the weight of tube, thermal insulation constructions and water with heat carrier - water and weight of tube and thermal insulation structur

with pair. Those who were determining during calculation for working order the flight/span between supports (for steam lines) and the dimensions of flexible compensators (upon consideration of their preliminary bracing in cold state) are checked against the cold state in which they accept:

a) the internal pressure of heat carrier equal to operating pressure;

b) the temperature of the wall of the tube of equal to 20°C;

c) calculated weight equal to the weight of tube, thermal insulation construction and water.

Nominal permissible stress and the modulus of elasticity of steel accept those corresponding to that temperature of the wall for which is performed the calculation.

The stress analysis of pipelines is performed for the most stressed section/cut i.e. for a section/cut, in which the combination of the effective loads creates maximum total equivalent stress.

During testing of section/cut with transverse weld of stress from all loads, except internal pressure, are determined with consideration the coefficient of strength of transverse weld.

Page 170.

The wall thickness of tube, which is located under internal pressure, is determined at the operating pressure of heat carrier according to the formulas:

With flexible compensators and auto/self-compensation (continuous tubes)

$$s' = \frac{P_{раб} D_н}{2(\sigma_{доп}\varphi + P_{раб})} + c \text{ мм}; \qquad (10.1)$$

With gasket compensators (notched tubes)

$$s' = \frac{P_{раб} D_н}{2(\sigma_{доп}\varphi + P_{раб})} + c \text{ мм}. \qquad (10.2)$$

where $P_{раб}$ – the operating pressure of heat carrier in kg/cm²; $D_н$ – a outside diameter of tube in mm; c is an addition to the calculated wall thickness of tube in mm; $\sigma_{доп}$ - permissible stress from internal pressure in kgf/mm² taken as equal to the nominal allowable stress $\sigma^*_{доп}$ and determine according to table 10.1; φ is a modulus of resistance of longitudinal or spiral weld; they accept for wrought pipes according to Table 10.2.

The wall thickness of tube s', determined by formulas (10.1) and (10.2), they round to the nearest larger size/dimension of s on the "assortment of the tubes of thermal grid/networks" or according to GOST.

The rounding wall thickness to smaller side is permitted to value not more than 3o/o from value (s' - c).

The value of additive c for seamless pipes is determined by the formula

$$c = A_1(s' - c) \text{ мм}, \qquad (10.3)$$

where A_1 is the coefficient, taken depending on the value of technological minus tolerances for the wall thickness of tubes, provided for GOST:

with the minus tolerance $-15\% \ldots A_1 = 0.2$
the same " $-10\% \ldots A_1 = 0.15$
$-5\% \ldots A_1 = 0.1$.

With the minus tolerances, which have intermediate value, the coefficient A_1 determines by interpolation.

The specific by formula (10.3) value c includes the compensation for the thinning of wall in the bends of tubes with condition that the mean radius of bend will be not less than 3.5 $D_н$.

During the application/use of the bent tubes with radii of bend smaller than those who were indicated are higher, the value of coefficient A_1 must be multiplied by value $\frac{3,5D_н}{R}$, where R is a radius of the axle/axis of the bent tube in mm.

The value of addition c for wrought pipes accepts equal to the value of the permissible minus deviations with respect to the thickness of steel plate with respect to the appropriate Gosts.

The value of addition c in all cases is taken not less than 0.5 mm.

For the used in thermal grid/networks seamless tubes of the common manufacturing precision according to GOST 8732-58* values of coefficient A_1 are taken as equal to 0.2, since

deviation with respect to wall thickness during the manufacture of these tubes with respect to the Gost comprises - 15o/o.

The value of addition c for wrought pipes according to GOST 4015-58 and 8696-62, which considers minus deviation with respect to the wall thickness of tube, is accepted according to GOST 8597-57 to steel roll and according to GOST 5681-57 to steel rolling thick-leaved:

(1) при толщине листа 5—5,5 мм $c=0,5$ мм; (3)
(2) то же, 6—7 мм $c=0,6$ мм;
8 мм и более (5) $c=0,8$ мм — для труб (4) по ГОСТ 4015—58
$c=0,7$ мм — для труб по ГОСТ 8696—62 (4)

Key: (1). With thickness of sheet. (2). the same. (3). for tubes. (4). according to GOST. (5). and more.

Table 101. Nominal allowable stresses in kgf/mm² (on "additions to the norms of the calculation of the cell/elements of steam boilers for the strength, accepted in 1958" by TsKTI).

(1) Расчетная температура стенки трубы в °С	(2) Номинальные допускаемые напряжения для марок стали					
	(3) Ст. 2	10	(3) Ст. 3	15	(3) Ст. 4	20
20	11,7	12	13	13,3	14,3	14,7
100	11,15	11,5	12,4	12,75	13,6	14,05
150	10,8	11,2	12,05	12,4	13,2	13,65
200	10,5	10,9	11,7	12,1	12,8	13,3
240	9,7	10	10,7	11,1	11,7	12,2
260	9,3	9,6	10,3	10,6	11,1	11,6
280	8,9	9,2	9,8	10,1	—	11,1
300	8,5	8,8	9,4	9,7	—	10,5
320	—	8,3	—	9,2	—	10
340	—	7,9	—	8,7	—	9,5
360	—	7,5	—	8,2	—	9,0
380	—	7,1	—	7,7	—	8,5
400	—	6,7	—	7,3	—	8
410	—	6,5	—	7,1	—	7,7
420	—	6,3	—	6,9	—	7,5
430	—	5,9	—	6,5	—	7,3

Notes: 1. For the intermediate values of the calculated temperature of the wall of tube the allowable stress determines by interpolation among two nearest values with the rounding of result to 0.05 kgf/mm² to the side of smaller value.

2. Values of σ°_{100} for temperatures of wall of tube 100 and 150°C are determined by interpolation.

Key: (1). The calculated temperature of the wall of tube in °C. (2). Nominal allowable stresses for the mark/brands of steel. (3). St.

Table 10.2. Moduli of resistance of weld.

(1) Конструкция шва и способ сварки	(2) Коэффициент прочности сварного шва
(3) Стыковой шов при ручной сварке с подваркой со стороны вершины шва	0,6
(4) Стыковой шов при ручной односторонней сварке при наличии со стороны вершины шва подкладки или кольца, прилегающих к основному металлу по всему периметру	0,9
(5) Стыковой шов при ручной односторонней сварке	0,7
(6) Стыковой шов с двусторонним проваром, выполняемый автоматической сваркой под слоем флюса	1
(7) Стыковой шов, свариваемый только с одной стороны автоматической сваркой под слоем флюса	0,8

Note. The modulus of resistance of spiral weld for wrought pipes according to GOST 8696-58 taking into account the permissible according to GOST lack of welding is taken as equal to 0.6, and according to GOST 8696-62 - 0.8.

Key: (1). Construction of weld and the welding method. (2) Modulus of resistance of weld. (3). The butt weld during manual welding with auxiliary welding from the apex/vertex of weld. (4). The butt weld during manual indirect welding when, from the apex/vertex, the weld of block/backing or ring is present, adjacent to base metal on entire perimeter. (5). The butt weld during manual indirect welding. (6). The butt weld with bilateral penetration, fulfilled by automatic submerged-arc welding. (7). The butt

weld, weldable only on the one hand by automatic submerged-arc welding.

Page 171.

The value of addition c for welded the work of the common manufacturing precision according to GOST 1753-53 are accepted equal to 10o/o, and about GOST 3262-62 - 15o/o of the wall thickness of tube.

In the wall thickness of tubes in all forms of the above-grade and underground packing of thermal grid/networks the reserve for external corrosion is not provided for.

With the assigned/prescribed wall thickness of tube testing this thickness on internal pressure is done by the comparison of the given voltage in the wall of tube from the internal pressure of heat carrier with allowable stress from internal pressure in this case it is necessary to observe the condition

$$\sigma_{пр} < \sigma_{доп} \text{ kgf/mm}^2. \qquad (10.4)$$

The given stress from internal pressure with the known wall thickness of tube is determined from the formulas:

with flexible compensators and the auto/self-compensation (continuous tubes)

$$\sigma_{пр} = \frac{P_{раб}(D_н - s^р)}{230\, s^р \varphi} \text{ kgf/mm}^2 \quad (10.5)$$

with gasket compensators (cut tubes)

$$\sigma_{пр} = \frac{P_{раб}(D_н - s^р)}{200\, s^р \varphi} \text{ kgf/mm}^2 \quad (10.6)$$

where $s^р$ is a calculated wall thickness of tube in mm.

The calculated wall thickness of tube is determined from the formula

$$s^р = s - c' \text{ мм}. \quad (10.7)$$

where s is a nominal wall thickness of tube in mm; c' is minus tolerance for the wall thickness of tube according to the appropriate Gost in mm.

For seamless pipes according to GOST 8732-58* common precision of manufacture during the permissible minus deviation with respect to the wall thickness of tube 15o/o

value c' is determined from the formula

$$c' = 0{,}15\,s \text{ MM.} \qquad (10.8)$$

For wrought pipes value c' accepts equal by 0.

Value c' in all cases is taken not less than 0.5 mm.

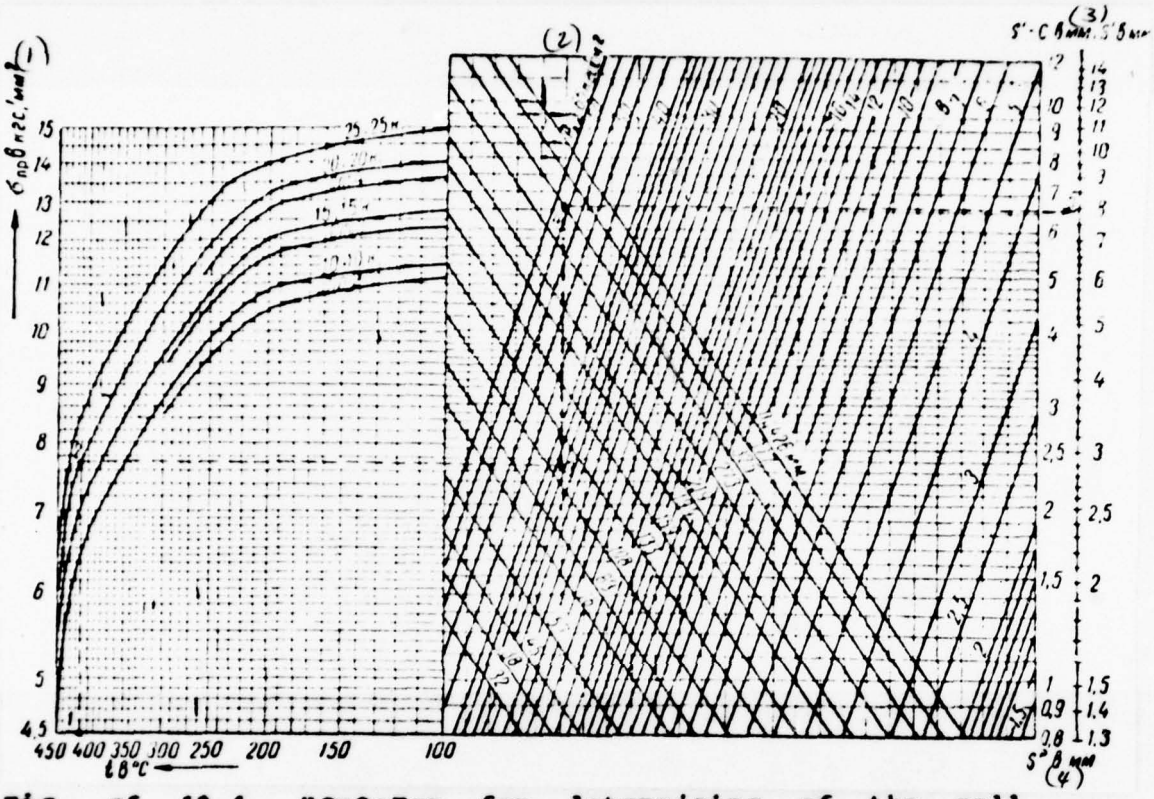


Fig. of 10.1. Homogram for determining of the wall thickness of tube s' and of the given stress from the internal pressure σ_{np} for the seamless continuous tubes.

Example. To determine the wall thickness of seamless pipe by outside diameter $D_н = 325$ mm with coolant pair with pressure $P_{раб} = 3$ kg/cm² temperature of t = 425°C; the material of the wall of tube steel of brand 20. Connecting in series points 1, 2, 3, 4 and 5, we determine at point

5 s' = 7.9 mm.

Key: (1). in kgf/mm². (2). kg/cm². (3). in mm, s' in mm. (4). in mm.

Page 172.

The thickness of the wall of the continuous tubes and the given stress from internal pressure for these tubes with the known wall thickness of tube can be determined according to the nomograms, given in Fig. 10.1 and 10.2.

The maximum flight/span between movable supports on the direct/straight section of pipeline from the condition of the strength of tube is determined from the formula

$$l_{\text{макс}} = \sqrt{\frac{12\sigma_3^1 W^p \varphi_1}{0{,}8q_1}} \text{ м}, \qquad (10.9)$$

where σ_3^1 is the permissible equivalent stress for weight and loads due to wind in kgf/mm²;

W^p - the moment of resistance of the cross section of tube with the calculated wall thickness of tube s^p in cm³

φ_1 - the modulus of resistance transverse weld; accept according to table 10.2;

q_1 - equivalent weight load in kG/m;

0.8 - the coefficient of plasticity.

The permissible equivalent stress for weight and loads due to wind is determined from the formula

$$\sigma_э^1 = \eta_1 \sigma_{доп} \text{ kgf/mm}^2 \qquad (10.10)$$

η_1 is the coefficient, depending on relationship/ratio $\sigma_{пр}/\sigma_{доп}$ and the type of compensators; Table 10.3, or they determine according to the curve/graph of Fig. 10.3.

The flight/span between movable supports with gasket compensators calculates according to those who stretch and according to compressive stresses; during calculation according to compressive stresses the coefficient ϕ_1 in formula (10.9) takes as equal to unity; as calculated they accept smaller of the obtained flight/spans. For a concrete/specific/actual value coefficient ϕ_1 can be predetermined, with which relationship/ratios $\sigma_{пр}/\sigma_{доп}$ one should perform calculation for elongation and with which for compression.

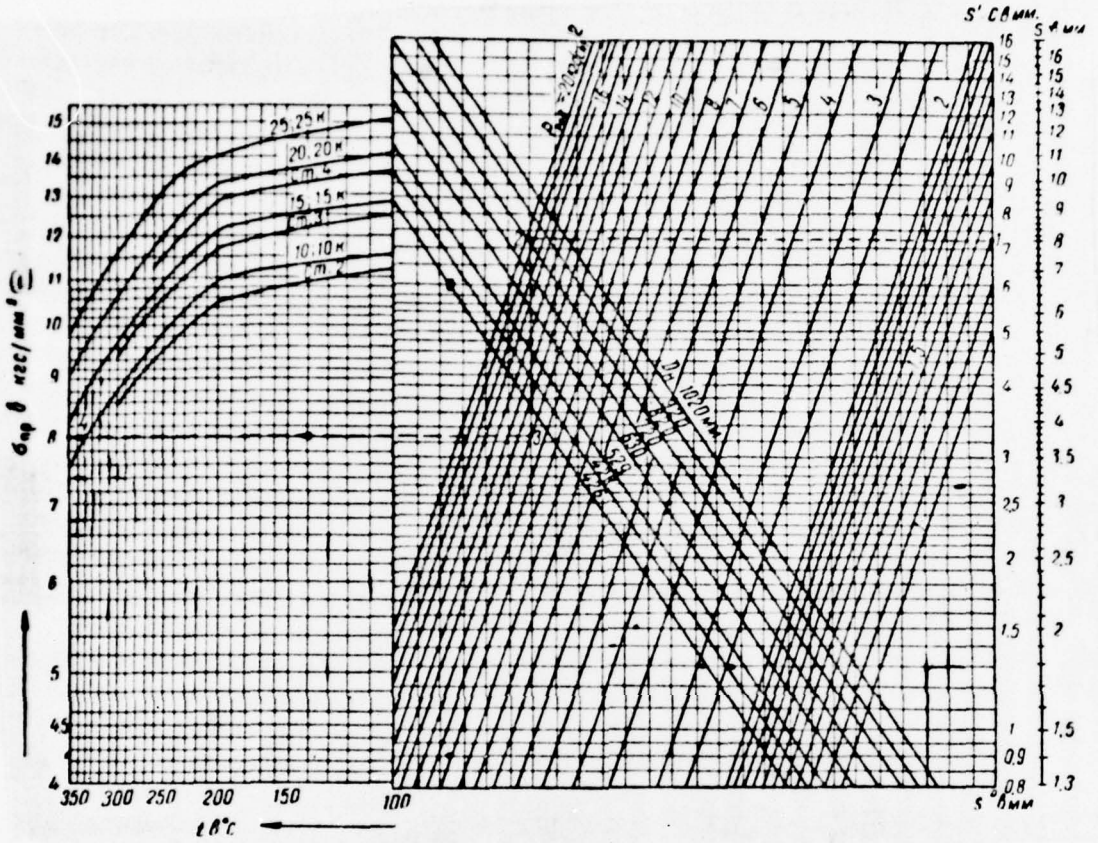


Fig. 10.2. Nomogram for determining of wall thickness of tube s' and of given stress from internal pressure of $\sigma_{пр}$ for welded continuous tubes.

Example. To determine the given stress from internal pressure for wrought pipe by outside diameter $D_н = 820$ mm, $s^р = 7{,}2$ mm, at a pressure of heat carrier $P_{раб} = 13$ kg/cm². Connecting in series points 1, 2, 3, and 4, we determine

at point $\sigma_{пр}=$ kgf/mm².

Key: (1). kgf/mm².

Page 173.

Thus, for instance, at the value of the coefficient ϕ_1 = 0.7 with relationship/ratio $\sigma_{пр}/\sigma_{доп}$ from 0 to 0.48 calculation one should produce only tensile stresses, but at value $\sigma_{пр}\ \sigma_{доп}$ from 0.48 to 1 - compressive stresses.

Equivalent weight load with underground pipe laying accepts equal to the calculated weight of pipeline in working or cold condition $q_э=q$ kG/m.

Equivalent weight load with above-grade pipe laying, which considers along with the weight of pipeline load due to wind, is determined according to formulae

$$q_э = m_в q \text{ kG/m} \qquad (10.14)$$

where $m_в$ is the coefficient, which considers the effect of load due to wind; they determine according to the

curve/graph of Fig. 10.4 depending on standard velocity head of wind q_o, given in Table 10.4.

Table 10.3. Formulas for determining the coefficient

(1) Способ компенсации	(2) Расчетные формулы
(3) Гибкие компенсаторы или самокомпенсация	$\eta_1 = \sqrt{1{,}2 - \left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2}$ (10.11)
(4) Сальниковые компенсаторы. Расчет труб по растягивающим напряжениям	$\eta_1 = 1{,}095$ (10.12)
(5) Сальниковые компенсаторы. Расчет труб по сжимающим напряжениям	$\eta_1 = \sqrt{1{,}2 - 0{,}75\left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2} - \frac{\sigma_{пр}}{2\,\sigma_{доп}}$ (10.13)

Key: (1). Method of compensation. (2). Calculation formulas. (3) Flexible compensators or auto/self-compensation. (4). Gasket compensators. Calculation of tubes according to tensile stresses. (5). Gasket compensators. Calculation of tubes according to compressive stresses.

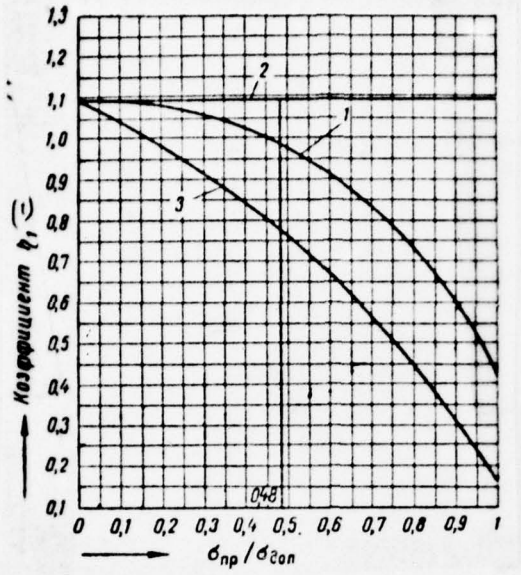


Fig. 10.3. Graph for determining coefficient η_1 1 - with flexible compensators or auto/self-compensation; 2 - with gasket compensators (calculation according to tensile stresses); 3 - with gasket compensators (calculation according to compressive stresses); $\sigma_{пр}$ is given stress from internal pressure in kgf/mm²; $\sigma_{доп}$ is allowable stress from internal pressure in kgf/mm².

Key: (1). Coefficient.

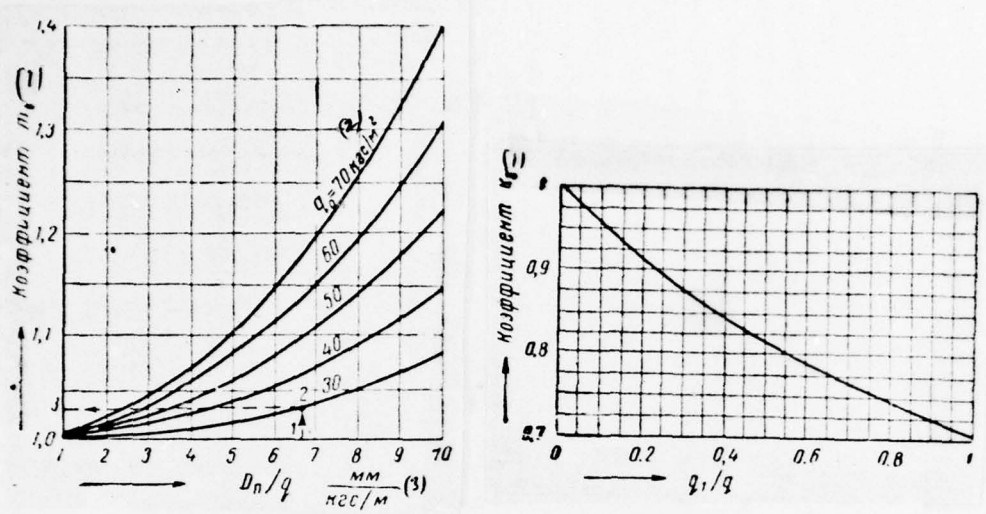


Fig. 10.4. Graph for determining influence coefficient of load due to wind $m_в$ q_0 is standard velocity head of wind in kgf/m²; D_n - outside diameter of cover layer of insulation construction; with lining "tube on tube" takes a equal to sum of outside diameters of cover layer of insulation construction of carrier and carried pipelines of mm; q - weight of pipelines in kG/m.

Key: (1). coefficient. (2). kgf/m². (3). mm/kg/m.

Fig. 10.5. Graph for determining coefficient of change in flight/span between movable supports of carrying pipeline with packing "tube on tube". q_1 is weight of the carried pipeline in kG/m; q - the weight of carrying pipeline in

kG/m.

Key: (1). coefficient.

Page 174.

During the use of a pipeline as framework for the tubing of smaller diameter (packing - "tube on tube") the flight/span between the movable supports of carrying pipeline is determined with consideration coefficient K_1, given on the graph of Fig. 10.5, which introduces on value flight/span, obtained from formula (10.9).

The maximum flight/spans between movable supports on direct/straight section for pipelines from the continuous tubes with any thicknesses of wall and the weight of tube can be determined according to the nomograms, given in Fig. 10.6 and 10.7.

The maximum flight/spans between movable supports on direct/straight sections for tubes on the "assortment of the tubes of thermal grid/networks" with above-grade packing are given in Table 10.5.

The maximum flight/spans between movable supports for end sections of pipelines, sections, which adjoin the rotation or the gasket compensators, are determined with consideration the coefficients, given in chapter 3, which are introduced on the value of the flight/spans, obtained from formula (10.9).

The maximum flight/span between movable supports on the permissible sagging/deflection for the direct/straight section of pipeline are determined from the formulas of VNIIST from the condition of the maximum sagging of pipeline in flight/span $f_{max} = 0{,}02D_y$ (see Fig. 10.8):

$$l_1 = \frac{\frac{24EJ^p}{q}\left(\frac{D_y}{50} + \frac{lx}{2}\right)}{x^3 \cdot 10^4} + x \text{ м}; \qquad (10.15$$

$$l_2 = 2x + \sqrt{x^2 - \frac{24EJ^p}{q \cdot 10^4} \cdot \frac{D_y}{50} \cdot \frac{1}{x^2}} \text{ м}. \qquad (10.16)$$

where D_y - the internal diameter of tube in m;

x - distance from lowest movable support to section/cut with maximum sagging/deflection in m;

q - the calculated weight of pipeline in running order in kG/m;

J_p - the moment of the inertia of the cross section of tube with the calculated wall thickness of tube in cm^4;

E - the modulus of elasticity of tube steel at the maximum temperature of heat carrier in g/cm^2.

i - the gradient/draft of pipeline.

Table 10.4. Standard velocity heads of wind for the height/altitude above the earth's surface to 10 m (on SNIP II-A.11-62).

(1) Районы СССР по приложению 2 главы СНиП II-А.11-62	I	II	III	IV	V	VI	VII
(2) Нормативный скоростной напор ветра q_0 в $кгс/м^2$	27	35	45	55	70	85	100

Note. With above-grade pipe laying at height/altitude from 10 to 20 m, the tabular values of velocity heads of wind increase on 3.5% to each meter of height/altitude over 10 m.

Key: (1). Areas of the USSR on appendix of 2 chapters SNIP. (2). Normal velocity head of wind q_0 in kgf/m^2.

Table 10.5. Maximum flight/spans between movable supports in m on the direct/straight sections of pipelines with above-grade packing (according to stress analysis).

(1) Размеры труб $D_н \times S$ в мм	(2) Компенсаторы П-образные или самокомпенсация						(3) Компенсаторы сальниковые			
	(4) Максимальные пролеты при параметрах теплоносителя: $P_{раб}$ в кгс/см², t в °С									
	$P_{раб}$=8, t=100	$P_{раб}$=16, t=150	$P_{раб}$=8, t=250	$P_{раб}$=13, t=300	$P_{раб}$=16, t=325; $P_{раб}$=21, t=350	$P_{раб}$=36, t=425	$P_{раб}$=8, t=100	$P_{раб}$=16, t=150	$P_{раб}$=8, t=250	$P_{раб}$=13, t=300
32× 2,5	—	—	3,1	3	2,5	2,1	—	—	—	—
38× 2,5	4,6	4,5	3,7	3,2	2,7	2,5	—	—	—	—
45× 2,5	5,2	5,1	4,2	3,7	3,2	2,7	—	—	—	—
57× 3,5	6,7	6,3	5,2	5,2	4,1	3,8	—	—	—	—
76× 3,5	7,5	7,3	6,4	5,8	5	4,4	—	—	—	—
89× 3,5	8,7	8	7	6,3	5,4	4,9	—	—	—	—
108× 4	9,4	8,7	7,8	7,1	6,2	5,6	9,6	9,1	7,8	7,4
133× 4	10,5	9,7	8,7	7,9	7	6,3	10,8	10,8	8,5	8,3
159× 4,5	11,8	10,9	10,1	9,2	8	7	12,3	11,7	9,7	9,4
194× 5	13	12,3	11,8	10,9	9,5	7,2	13,4	13,1	11,2	10,9
219× 6	14,6	13,9	13,1	12,3	10,7	9,2	17,4	14,8	12,8	12,3
273× 7	16,8	15,8	15,7	15,1	13,6	10,0	17,4	16,8	15	14,6
325× 8	18,9	17,8	17,8	17,3	14,9	13,9	19,6	19,2	17	17
377× 9	20,7	19,6	19,3	18,9	17	15	21,5	21,2	18,5	18,3
426× 9	—	—	—	—	19	—	—	—	—	—
426× 11	—	—	—	—	—	15,4	—	—	—	—
426× 6	19,6	17,8	18,4	17,9	—	—	21	17,2	19,5	18,3
478× 6	19,9	17,9	19	17,9	—	—	21,7	16,5	20,4	17,3
529× 6	19,6	17,9	19,4	18,3	—	—	22	13,5	21,2	16,8
630× 7	22,8	19,7	21,7	21,4	—	—	24,6	17	23,6	19,8
720× 7	22,5	19,2	22,3	21,9	—	—	24,6	13,4	25	15,2
820× 8	25	20,4	24,1	22,5	—	—	26,4	14,7	25,7	15,4
920× 9	27	22,1	26,2	24,3	—	—	23,9	16,6	27,7	18,9
1020×10	28,6	23,7	28,2	26,2	—	—	31,1	18,1	30	21,7

Notes: 1. Heavy line is the boundary/interface between tubes according to GOST 8732-58* and GOST 4015-58.

2. During determination of maximum flight/spans between supports, it is accepted: a) modulus of resistance transverse weld - for tubes with $P_{раб}$=36 kg/cm² and t = 425°C internal diameter from 100 to 400 mm ϕ_1 = 0.9; for remaining tubes ϕ_1 = 0.7; b) coefficient of strength of

longitudinal weld ϕ = 0.8; c) mark/brand they will stop for seamless pipes with $P_{раб} = 36$ kg/cm², t = 425°C - steel 20; for seamless pipes with other parameters of heat carrier - steel 10: for wrought pipes - St. 3.

3. In present table are given smaller of maximum flight/spans, obtained from calculation of tubes for working and cold state (for steam lines).

Key: (1). Size/dimensions of tubes $D_н$ x s in mm. (2). Compensators P-shaped or auto/self-compensation. (3). Compensators are gasket. (4). Maximum flight/spans in the parameters of the heat carrier: $P_{раб}$ in kg/cm², t in °C.

Page 175.

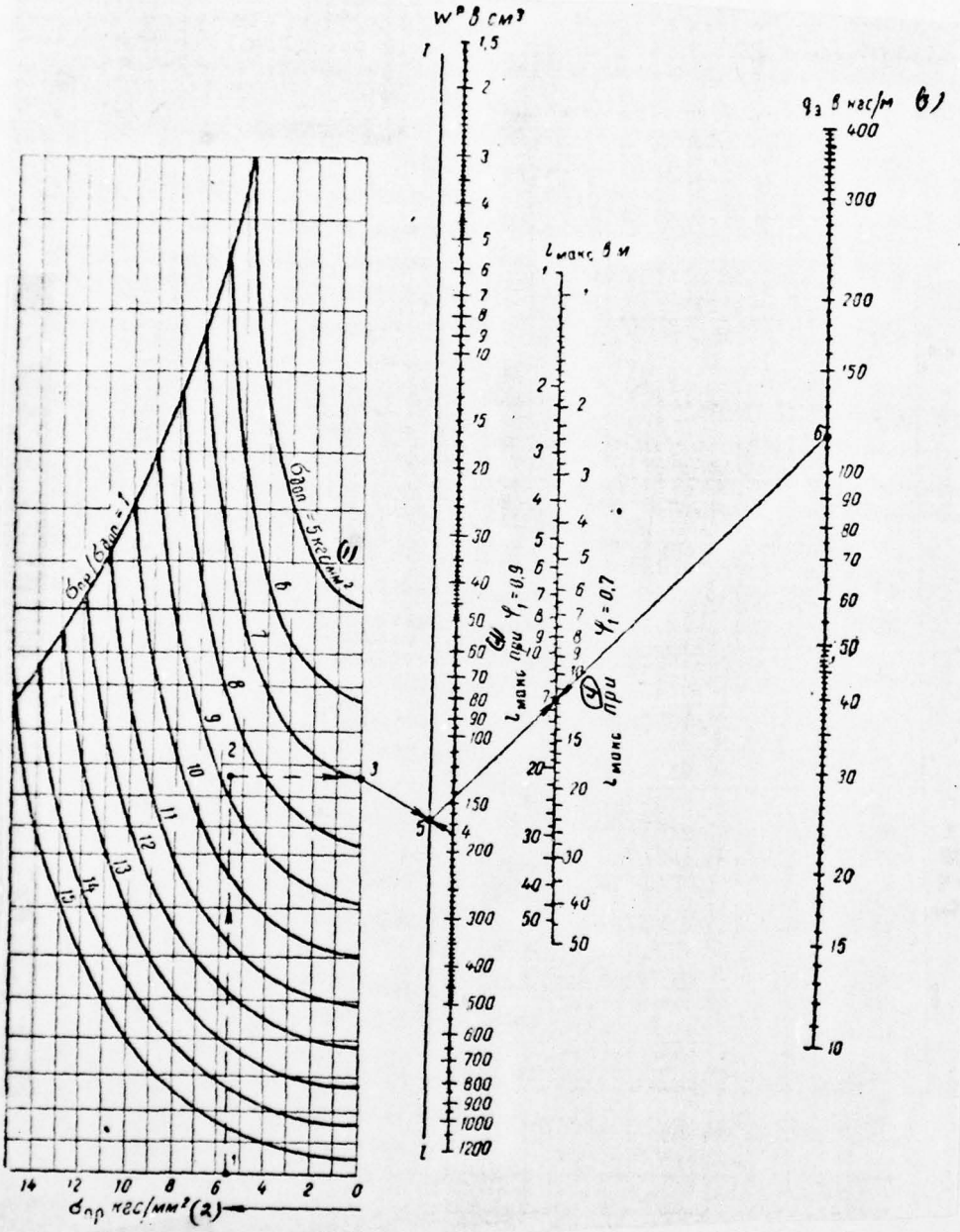


Fig. 10.6. Nomogram for determining maximum flight/span

between movable supports $l_{макс}$ on direct/straight section for pipelines from seamless continuous tubes from stress analysis.

Example. To determine the value of maximum flight/span on the direct/straight section of pipeline at the given stress from internal pressure $\sigma_{пр}=5{,}82$ kgf/mm², the modulus of resistance transverse weld $W_{P}=179$ kgf/mm², moment of resistance $q_{0}=113$ cm³ and to equivalent weight load kG/m. Connecting in series points 1, 2, 3, 4, 5, 6, we find in point 7 $l_{макс}=11{,}3$ m.

Key: (1). kgf/mm². (2). kgf/mm². (3). kG/m. (4). with.

Page 176.

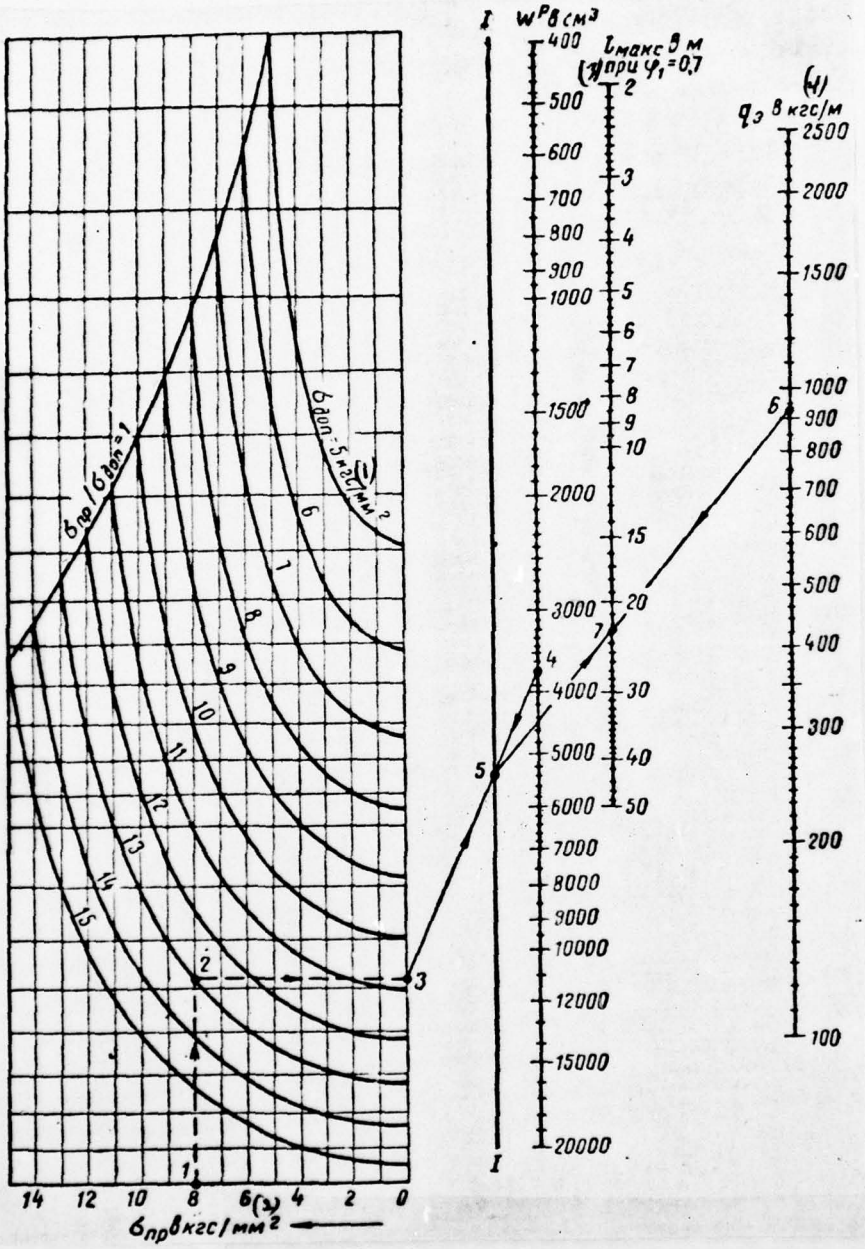


Fig. 10-7- Nomogram for determining maximum flight/span

between movable supports $l_{макс}$ on direct/straight section for pipelines from welded continuous tubes from stress analysis.

Key: (1). kgf/mm². (2). kgf/mm². (3). with. (4). kG/m.

Page 177.

During the determination of the flight/span between movable supports from formulas, one should, being given value x, determine l_1 and l_2. The flight/span between movable supports according to the permissible sagging/deflection will be determined at such value of x, by which $l_1 \approx l_2$.

for the pipelines of thermal grid/networks with the minimum gradient/draft i = 0.002, for determining the flight/span between supports from the permissible sagging/deflection, it is possible to use the simpler approximation formula

$$l = 3{,}98 \sqrt[3]{\frac{EJ^p}{q \cdot 10^6}} - 1{,}4 \text{ м}. \qquad (10.17)$$

The maximum flight/spans between movable supports, determined by the permissible sagging/deflection for tubes on

the "assortment of the tubes of thermal grid/networks", are given in table 10.6.

With packing in the impassable channels of large-diameter tubes the value of flight/span they limit by ultimate load on the pillow of saddle. With the above-ground laying of pipes of different diameters on piers the flight/span between supports they limit by the standardized space of standard piers. With the above-grade tubing of different diameters on the separate supports the flight/span is accepted according to the optimum conditions of direct support for the support of the greatest quantity of tubes without the device of additional inner bearings. With packing "tube on tube" (or with the suspension of "tube to tube"). the flight/span of the carried tube accepts multiple to the taken flight/span of carrying tube. With packing according to the walls of buildings the flight/span accepts multiple to the space of carrying columns of building.

In all cases the taken flight/span between movable supports must not exceed maximum flight/span in stress analysis and for the permissible sagging/deflection, in this case the permissible bending compensating stress, received with the taken flight/span, must provide the necessary

dimensions of compensators and length of the sections of auto/self-compensation.

The permissible bending compensating stress, which appears during the compensation for thermal elongations by flexible compensators or auto/self-compensation, determines from the formulas:

for the pipelines, arrange/located in the horizontal plane

$$\sigma^1_{и.к} = \sqrt{\left(\sigma^1_{экв} - \frac{\sigma^{оп}_{тр}}{\varphi_1}\right)^2 \cdot \left(\frac{\varphi_1}{0{,}8}\right)^2 - \sigma^2_и} - \sigma_{и.в} \text{ kgf/mm}^2 \quad (10.18)$$

for the pipelines, arrange/located in the vertical plan

$$\sigma^1_{и.к} = \left(\sigma^1_{экв} - \frac{\sigma^{оп}_{тр}}{\varphi_1}\right)\frac{\varphi_1}{0{,}8} - \sigma_и - \sigma_{и.в} \text{ kgf/mm}^2 \quad (10.19)$$

for $\sigma^1_{экв}$ - the permissible equivalent stress from all loads, which effect on pipeline, except internal pressure in kgf/mm²;

$\sigma^{оп}_{тр}$ longitudinal stress from forces of friction in movable supports in kgf/mm²;

$\sigma_{и}$ - bending stress from the dead weight of pipeline in kgf/mm²;

$\sigma_{и.в}$ - bending stress from load due to wind in kgf/mm² (is considered with above-grade pipe laying);

φ_1 - the modulus of resistance transverse weld, are accepted according to Table 10.2.

Permissible longitudinal stress, which appears during the compensation for thermal elongations by gasket compensators, determines from the formula

$$\sigma^{1}_{р.к} = \sigma^{1}_{экв}\varphi_1 - 0{,}8\sqrt{\sigma^2_{и} + \sigma^2_{и.в}}\ \text{kgf/mm}^2. \qquad (10.20)$$

In formulas (10.18) and (10.19) are not taken into account longitudinal stresses from the force of elastic deformation of flexible compensators or sections of auto/self-compensation, since the value of these stresses is insignificant and does not affect the result of calculation.



Fig. 10.8. Diagram of sagging of pipeline 1 - movable support; 2 - pipeline.

Table 10.6. Maximum flight/spans between movable supports on direct/straight sections of pipelines with above-grade packing (according to calculation for sagging/deflection).

(1) Размеры труб $D_н \times s$ в мм	(2) Максимальные пролеты между подвижными опорами в м при параметрах теплоносителя $P_{раб}$ в кгс/см², t в °С					
	$P_{раб}=8$; $t=100$	$P_{раб}=16$, $t=150$	$P_{раб}=8$, $t=200$	$P_{раб}=13$, $t=300$	$P_{раб}=16$, $t=325$; $P_{раб}=21$, $t=350$	$P_{раб}=36$, $t=425$
32×2,5	—	—	2,1	2	2	1,8
38×2,5	3	2,7	2,5	2,3	2,3	2,2
45×2,5	3,4	3,2	2,9	2,7	2,6	2,5
57×3,5	4,4	4,3	3,8	3,8	3,6	3,4
76×3,5	5,3	5,2	4,9	4,8	4,6	4,4
89×3,5	6,1	5,9	5,5	5,4	5	5
108×4	6,8	6,3	6,3	6,2	5,9	5,7
133×4	8	7,9	7,5	7,1	6,9	6,8
159×4,5	9,2	9	8,7	8,3	8	7,8
194×5	10,6	10,4	10,5	10,2	9,7	9,4
219×6	11,9	11,7	11,9	11,3	11,1	10,6
273×7	14,4	14,2	14,6	14	13,4	13,3
325×8	16,6	16,2	17,2	16,7	16	15,5
377×9	18,4	18,3	19,4	18,9	18,3	17,8
426×9	—	—	—	—	20	—
426×11	—	—	—	—	—	20
426×6	18,2	18	20,1	19,5	—	—
478×6	19,4	19,3	21,9	21	—	—
526×6	20,7	20,5	23,4	22,7	—	—
630×7	23,5	23,5	27,4	26,7	—	—
720×7	25,5	25,5	30,3	29,6	—	—
820×8	27,8	27,7	34,2	33	—	—
920×9	30,8	30,2	38,2	36,9	—	—
1020×10	33	32,5	42,1	40,8	—	—

Notes: 1. Heavy line is the boundary/interface between tubes according to GOST 8732-58* and GOST 4015-58.

2. Table is comprised with gradient of pipeline i = 0.002.

Key: (1). Size/dimensions of tubes $D_н \times s$ in mm. (2). Maximum flight/spans between movable supports in m in the parameters of heat carrier $P_{раб}$ in kg/cm², t in °C.

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3 OF 6
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Page 178.

The permissible equivalent stress from all loads, which effect on pipeline, except internal pressure, is determined from the formula

$$\sigma^1_{экв} = \eta_2 \sigma_{доп} \text{ kgf/mm}^2, \qquad (10.21)$$

where η_2 is the coefficient, depending on relationship/ratio $\frac{\sigma_{пр}}{\sigma_{доп}}$ and the type of compensators; they calculate according to the formulas, given in Table 10.7, or they determine according to the curve/graph of Fig. 10.9.

Permissible longitudinal stress, which appears with gasket compensators, is determined according to those who stretch or according to compressive stresses; during calculation according to compressive stresses the coefficient φ_1 in formula (10.20) takes as equal to unity. As allowable stress they accept smaller of those who were obtained the calculation for elongation and compression.

Table 10.7. Formulas for determining the coefficient η_2

(1) Способ компенсации	(2) Расчетные формулы
(3) Гибкие компенсаторы или самокомпенсация	$\eta_2 = \sqrt{2{,}1 - \left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2}$ (10.22)
(4) Сальниковые компенсаторы. Расчет труб по растягивающим напряжениям	$\eta_2 = 1{,}15$ (10.23)
(5) Сальниковые компенсаторы. Расчет труб по сжимающим напряжениям	$\eta_2 = \sqrt{2{,}1 - 0{,}75\left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2} - \frac{\sigma_{пр}}{2\sigma_{доп}}$ (10.24)

Key: (1). Method of compensation. (2). Calculation formulas. (3). Flexible compensators or auto/self-compensation. (4). Gasket compensators. Calculation of tubes according to tensile stresses. (5). Gasket compensators. Calculation of tubes according to compressive stresses.

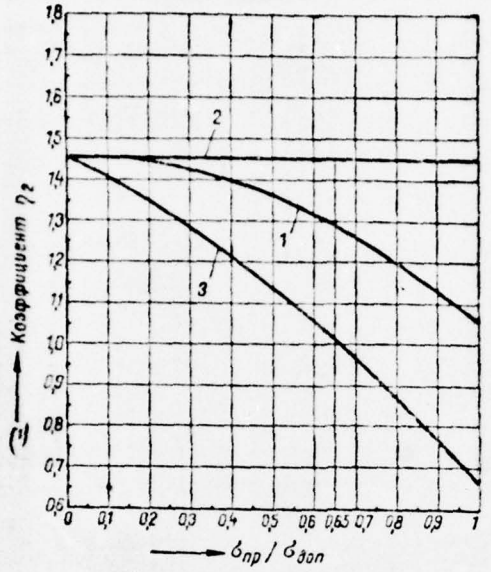


Fig. 10.9. Graph for determining coefficient η_2 1 - with flexible compensators or auto/self-compensation; 2 - with gasket compensators (calculation according to tensile stresses); 3 - with gasket compensators (calculation according to compressive stresses); $\sigma_{пр}$ is the given stress from internal pressure in kgf/mm²; $\sigma_{доп}$ is allowable stress from internal pressure in kgf/mm².

Key: (1). Coefficient.

Table 10.8. Permissible compensating stresses $\sigma^{I}_{н.к}$ in kg/mm² for the calculation of n-shaped compensators with the maximum flight/spans between movable supports.

(1) Состояние трубопровода	(2) Характеристика труб	(3) Марка стали	(4) Допускаемые компенсационные напряжения при параметрах теплоносителя: $P_{раб}$ в кгс/см², t в °С						
			$P_{раб}$=8, t=100	$P_{раб}$=16, t=150	$P_{раб}$=8, t=250	$P_{раб}$=13, t=300	$P_{раб}$=16, t=325	$P_{раб}$=21, t=350	$P_{раб}$=36, t=425
(5) Рабочее	(6) Бесшовные	10	9,5	9,3	8,1	7,3	6,8	6,4	—
		20	11,7	11,3	9,8	8,7	8,1	7,7	6,1; 7,9*
	(7) Бесшовные и сварные	Ст. 3	10,3	10	8,7	7,8	—	—	—
(9) Холодное	(8) Бесшовные	10	9,55						—
		20	12,2						12,2; 15,7*
	(10) Бесшовные и сварные	Ст.3	10,8				—	—	—

Notes: 1. The permissible compensating stresses are given for a section/cut on compensator (without taking into account of forces of friction). 2. Permissible compensating stresses are determined with modulus of resistance transverse weld ϕ_1 = 0.7, and for values, noted by chain wheel, with ϕ_1 = 0.9.

Key: (1). State of pipeline. (2). Characteristic of tubes. (3). Trademark of steel. (4). Permissible compensating stresses in the parameters of the heat carrier: in kg/cm², t in °C. (5). Working. (6) seamless. (7). Seamless

and welded. (8). Seamless. (9). Cold. (10). Seamless and welded.

Page 179.

For the concrete/specific/actual value of coefficient ϕ_1 just as during the determination of the flight/span between movable supports, it is possible to predetermine, with which relationship/ratios $\sigma_{пр}/\sigma_{доп}$ one should perform calculation for compression and with which for elongation. Thus, for instance, at the value of coefficient $\phi_1 = 0.7$ in tensile stresses one should perform calculation with relationship/ratios $\sigma_{пр}/\sigma_{доп}$ from 0 to 0.65, and according to compressive stresses when $\sigma_{пр}/\sigma_{доп}$ from 0.65 to 1.

The permissible compensating stresses for the calculation of U-shaped compensators from tubes according to the "assortment of the tubes of thermal grid/networks" (according to GOST 8732-58* and GOST 4015-58) are given in table 10.8 with the maximum flight/spans between movable supports, indicated in table 10.5, but in table 10.9 - for the averaged conditions of the calculation of pipelines with the flight/spans between movable supports, given in table 3.1.

Longitudinal stress from forces of friction in movable supports is determined from the formula

$$\sigma_{тр}^{оп} = \frac{P_{тр}^{оп}}{f^{р}} \text{ kgf/mm}^2 \qquad (10.25)$$

where $P_{тр}^{оп}$ - force of friction in movable supports in kgf (see Chapter 11);

$f^{р}$ - the cross-sectional area of the wall of tube with the calculated wall thickness of tube $s^{р}$ in mm².

Bending stress from the dead weight of pipeline is determined from the formula

$$\sigma_{и} = \frac{ql^2}{B W^{р}} \text{ kgf/mm}^2 \qquad (10.26)$$

where q is calculated weight of pipeline in kG/m;

l - the distance between movable supports in m;

B - the coefficient, which determines supporting moments, depending on the arrangement of calculated

flight/span, taken:

for a flight/span on direct/straight section. 12;

The same, between the nearest to rotation supports (before and after rotation). 5.33;

The same, between last/latter and penultimate supports (before and after rotation).

(before the plug/silencer, before flexible compensator of rotation). 3;

for last/latter two flight/spans from each side of gasket compensator. 8.

Bending stress from load due to wind with above-grade pipe laying is determined from the formula

$$\sigma_{и.в} = \frac{q_0 c D_н l^2}{B W_р} \text{ kgf/mm}^2 \qquad (10.27)$$

where c is an aerodynamic coefficient; take as equal to 1.4;

q_0 - standard velocity head of wind in kgf/m^2; is accepted according to table 10.4;

$D_н$- the outside diameter of a cover layer of insulation construction in m.

The calculated bending compensating stresses, determined by calculation for the compensation for thermal elongations with flexible compensators and during the auto/self-compensation for pipelines, must be not the more the allowable stresses, received from formulas (10.18) and (10.19), and they must satisfy the following conditions:

1) during calculation for auto/self-compensation without cold bracing (calculation for working order)

$$\sigma^{к}_{и(раб)} \leqslant \sigma^{1}_{и\,к\,(раб)} \quad kgf/mm^2 \qquad (10.28)$$

2) with flexible compensators or during auto/self-compensation with cold bracing (calculation on is working or to the cold state);

a) during calculation for working order (with testing of the stresses in the cold state):

$$\sigma^{к}_{и\,(раб)} \leq \sigma^{1}_{и.к(раб)} \quad \text{kgf/mm}^2 \qquad (10.29)$$

$$\sigma^{к}_{и(раб)} \leq \sigma^{1}_{и.к\,(хол)} \frac{E_{(раб)}\, e_{(раб)}}{E_{(хол)}\, e_{(хол)}} \quad \text{kgf/mm}^2 \qquad (10.30)$$

b) during calculation for cold state (with testing of the stresses in running order):

$$\sigma^{к}_{к\,(хол)} \leq \sigma^{1}_{и.к\,(хол)} \quad \text{kgf/mm}^2 \qquad (10.31)$$

$$\sigma^{к}_{и\,(хол)} \leq \sigma^{1}_{и.к\,(раб)} \frac{E_{(хол)}\, e_{(хол)}}{E_{(раб)}\, e_{(раб)}} \quad \text{kgf/mm}^2 \qquad (10.32)$$

where $\sigma^{к}_{и(раб)}$ and $\sigma^{к}_{и(хол)}$ are the calculated bending compensating stresses in working and cold condition, received from calculation for the compensation for thermal elongations in kgf/mm²;

$\sigma^{1}_{и.к\,(раб)}$ and $\sigma^{1}_{и.к\,(раб)}$ are the permissible bending compensating stresses in worker and cold the states in working and cold condition, obtained from stress analysis, in kgf/mm²;

$E_{(раб)}$ and $E_{(хол)}$ are moduli of elasticity of tube steel in working and cold condition in kg/cm²;

$e_{(раб)}$ and $e_{(хол)}$ - the coefficients, which consider the effect of the preliminary bracing of compensators, possible inaccuracy in its accomplishing and the effect of relaxation of compensating strasses in working and cold condition.

Table 10.9. Permissible compensating stresses $\sigma^{t}_{и.к}$ in kgf/mm² for the averaged conditions of the calculation of pipelines

(1) Для расчета компенсаторов на холодное состояние	(2) Для расчета участков самокомпенсации на рабочее состояние							
(3) Допускаемые компенсационные напряжения при параметрах теплоносителя: $P_{раб}$ в кгс/см², t в °С								
$P_{раб}=16$, $t=150$; $P_{раб}=$, $t=250$; $P_{раб}=13$, $t=300$	$P_{раб}=16$, $t=325$	$P_{раб}=21$, $t=350$	$P_{раб}=36$, $t=425$	$P_{раб}=16$, $t=150$	$P_{раб}=$, $t=250$	$P_{раб}=13$, $t=300$; $P_{раб}=16$; $t=325$	$P_{раб}=21$, $t=350$	$P_{раб}=36$, $t=425$
11	11	11,5	16	8	9	7	6	6

Key: (1). For the calculation of compensators for cold state. (2). For the calculation of the sections of auto/self-compensation for working order. (3). Permissible compensating stresses in the parameters of the heat carrier in kg/cm², t in °C.

pages 180-181.

Table 10.10. Example of the calculation of pipeline with U-shaped compensators for the strength with above-grade lining.

(1) Элемент расчета	(2) Единица измерения	(3) Расчетные формулы и обозначения	(4) Результаты расчета	
			(5) на рабочее состояние	(6) на холодное состояние
Теплоноситель пар: (7) давление	(5) кгс/см²	$P_{раб}$	21	
температура (9)	°C	t	350	20
Наружный диаметр трубы (10)	мм	$D_н$	219	
Номинальная толщина стенки трубы по ГОСТ 8732—58* (11)	»	s	6	
Минусовое отклонение по толщине стенки трубы по ГОСТ 8732—58* (12)	%		−15	
Материал стенки трубы (13)	—	—	(13a) Сталь 10	
Модуль упругости стали (14)	(8) кгс/см²	E	$1{,}695 \cdot 10^6$	$2{,}05 \cdot 10^6$
Коэффициент прочности поперечного сварного шва (15)	—	φ_1	0,7	
Расстояние от неподвижной опоры до оси П-образного компенсатора (16)	м	L	50	
Пролет между подвижными опорами на компенсаторе (17)	»	l	6	
Вес паропровода (18)	(9) кгс/м	q	119	153
Нормативный скоростной напор ветра (20)	(8) кгс/м²	q_0	30	
Аэродинамический коэффициент (21)	—	c	1,4	
Наружный диаметр покровного слоя изоляционной конструкции (22)	м	$D_п$	0,51	
Коэффициент трения подвижных (скользящих) опор (23)	—	f	0,3	
Расчетная толщина стенки трубы (24)	мм	$s^р = s - 0{,}15s$	5,1	
Внутренний диаметр трубы при $s^р$ (25)	мм	$D_в^р = D_н - 2s^р$	208,8	

Table 10.10 continued

(26) Момент сопротивления поперечного сечения трубы при s^p	$см^3$	$W^p = \frac{\pi}{32} \frac{(D_н^4 - D_в^4)}{D_н}$	179	
Площадь поперечного сечения стенки трубы при s^p (27)	$мм^2$	$f^p = 0{,}785 (D_н^2 - D_в^2)$	3420	
Допускаемое напряжение от внутреннего давления по табл. 10.1 (28)	(1) $кгс/мм^2$	$\sigma_{доп}$	7,7	12
Приведенное напряжение от внутреннего давления (29)	»	$\sigma_{пр} = \frac{P_{раб}(D_н - s^p)}{230 s^p}$	3,83	
(30) Определение максимального пролета между подвижными опорами				
Отношение приведенного напряжения от внутреннего давления к допускаемому (31)	—	$\sigma_{пр} / \sigma_{доп}$	0,498	0,319
Коэффициент для определения допускаемого эквивалентного напряжения от весовых и ветровых нагрузок (32)	—	$\eta_1 = \sqrt{1{,}2 - \left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2}$	0,975	1,05
Допускаемое эквивалентное напряжение от весовых и ветровых нагрузок (33)	(1) $кгс/мм^2$	$\sigma_э^д = \eta_1 \sigma_{доп}$	7,5	12,6
Соотношение (34)	(35) $\frac{мм}{кгс/м}$	$D_н / q$	4,28	3,33
Коэффициент влияния ветровой нагрузки по графику рис. 10.4 (36)	—	$m_в$	1,01	1,01
Максимальный пролет между подвижными опорами на прямом участке (37)	$м$	$l_{макс} = \sqrt{\frac{15 \sigma_э^д W^p \eta_1}{q m_в}}$	10,7	12,3
Максимальный пролет между ближайшими к повороту опорами (на компенсаторе) (38)	»	$l = 0{,}67 l_{макс}$	7,15 > 6	8,25 > 6
Изгибающее напряжение от весовой нагрузки при $l = 6$ м (39)	(1) $кгс/мм^2$	$\sigma_и = \frac{ql^2}{5{,}33 W^p}$	4,53	5,83
Изгибающее напряжение от ветровой нагрузки при $l = 6$ м (40)	»	$\sigma_{ив} = \frac{q_0 c D_н l^2}{5{,}33 W^p}$	0,815	
Коэффициент для определения эквивалентного напряжения от всех нагрузок, кроме внутреннего давления (41)	—	$\eta_в = \sqrt{2{,}1 - \left(\frac{\sigma_{пр}}{\sigma_{доп}}\right)^2}$	1,36	1,415
Допускаемое эквивалентное напряжение от всех нагрузок, действующих на трубопровод, кроме внутреннего давления (42)	(1) $кгс/мм^2$	$\sigma_{экв}^д = \eta_2 \sigma_{доп}$	10,5	17
Допускаемое изгибающее компенсационное напряжение для сечения на компенсаторе (43)	(1) $кгс/мм^2$	$\sigma_{и.к}^д = \sqrt{\sigma_{экв}^{д\,2} \frac{\sigma_1^2}{0{,}6\sigma_т} - \sigma_и^2} - \sigma_{и.в}$	7	12,8

Note.

The given stress from internal pressure $\sigma_{пр}$ the less allowable stress in running order: 3.83 kg/mm² < 7.7 kgf/mm², the consequently assigned/prescribed wall thickness of tube s = 6 mm satisfies the conditions of the stress analysis of tube.

On the basis of the obtained the calculation permissible compensating stresses in running order $\sigma^{д}_{н.к\ (раб)} = 7$ kgf/mm² and cold state $\sigma^{д}_{н.к\ (хол)} = 12.8$ kgf/mm² select allowable stresses for calculation for compensation taking into account preliminary bracing; for this parameter of heat carrier the coefficient η which considers effect of the preliminary bracing of compensator in size/dimension of 50o/o of complete thermal elongation and relaxation of compensating stresses, is accepted according to table 10.12

$$\eta_{хол}=0,7;\ \eta_{раб}=0,5.$$

From formula (10.32) we will obtain the permissible compensating stress for calculation for compensation in the cold state:

$$\sigma^{д}_{н.к\ (хол)} = \sigma^{д}_{н.к\ (раб)} \frac{E_{хол}\,\eta_{хол}}{E_{раб}\,\eta_{раб}} = 11.5 \text{ kgf/mm}^2.$$

Key: (1). cell/element is calculation. (2). Unit of measurement. (3). Calculation formulas and designations. (4). Results of calculation. (5). to working order. (6). to cold state. (7) Heat carrier of vapor: pressure. (8). kg/cm². (9). temperature. (10). Outside diameter of tube. (11). Nominal wall thickness of tube according to GOST 8732-58.* (12). Minus deviation with respect to the wall thickness of tube according to GOST 8732-58.* (13). Material of the wall of tube. (13a). Steel. (14). Modulus of elasticity of steel. (15). modulus of resistance -transverse weld. (16). Distance from fixed support to the axle/axis of U-shaped compensator. (17). Flight/Span between movable supports on compensator. (18). Weight of steam line. (19). kG/m. (20). Standard velocity head of wind. (21). Aerodynamic coefficient. (22). Outside diameter of a cover layer of insulation construction. (23). Coefficient of the friction of mobile (sliding) supports. (24). Calculated wall thickness of tube. (25). Internal diameter of tube with. (26). Moment of resistance of the cross section of tube with. (27). Cross-sectional area of the wall of tube with. (28). Allowable stress from internal pressure on Table 10.1. (29) Given stress from internal pressure. (30). Determination of the maximum flight/span between movable supports. (31). Ratio of the given stress from internal pressure to permissible.

(32). Coefficient for determining the permissible equivalent stress from weight and loads due to wind. (33). Permissible equivalent stress from weight and wind loads. (34). Relationship/ratio. (35). мм/kg/м. (36). Influence coefficient of load due to wind in the curve/graph of Fig. 10.4. (37). Maximum flight/span between movable supports on direct/straight section. (38). Maximum flight/span between the nearest to rotation supports (on compensator). (39). Bending stress from weight load when $z = 6$ м. (40). Bending stress from load due to wind when $z = 6$ м. (41) Coefficient for determining the equivalent stress from all loads, except internal pressure. (42). Permissible equivalent stress from all loads, which effect on pipeline, except internal pressure. (43) Permissible bending compensating stress for a section/cut on compensator.

Page 182.

Calculated longitudinal stress, which appears during the compensation for thermal elongations by gasket compensators, determines from the formula

$$\sigma_{p.к} = \sigma_{тр}^{он} + \sigma_{тр}^{с} \text{ kgf/мм}^2 \qquad (10.33)$$

where $\sigma_{тр}^{оп}$ is stress from forces of friction in movable supports in kgf/mm²;

$\sigma_{тр}^{с}$ - stress from forces of friction in gasket compensator in kgf/mm².

Stress from forces of friction in gasket compensator is determined from the formula

$$\sigma_{тр}^{с} = \frac{P_c}{fp} \text{ kgf/mm}^2 \qquad (10.34)$$

where P_c - force of friction in gasket compensator in kgf (see Chapter 11).

The value of calculated longitudinal stress must satisfy the condition

$$\sigma_{р.к} \leq \sigma_{р.к}^{1} \text{ kgf/mm}^2. \qquad (10.35)$$

An example the stress analysis of tubes with above-grade pipe laying with U-shaped compensators is given in Table 10.10.

10.2. Methods of the compensation for the thermal elongations of pipelines.

The thermal elongations of pipelines at the temperature of heat carrier from 50°C and above must be absorbed by the special compensators, which prevent pipeline from the emergence of the inadmissible strains and stresses.

as compensators are applied flexible (Π- or S-shaped) or gasket and corrugated compensators. The rotations of pipelines on the route of thermal grid/networks as a rule, are utilized for auto/self-compensation. The selection of the method of compensation depends on the parameters of heat carriers, method of the packing of the thermal grid/network and other local conditions.

Flexible compensators Π- and S-shaped are applied in above-grade pipe laying for all diameters of tubes independent of the parameters of heat carrier; at a pressure of heat carrier to 16 kg/cm² for tubes by

diameter from 25 to 200 mm at packing in channels, tunnels and common/general/total collector/receptacles; for tubes by diameter from 25 to 100 mm at channel-free packing; for the tubes of all diameters at the pressure of heat carrier above 16 kg/cm² at all methods of packing.

Gasket compensators in thermal grid/networks are applied steel at a pressure of heat carrier to 16 kg/cm² in packing in channels, tunnels and common/general/total collector/receptacles - for pipelines by diameter 250 mm and more, but with channel-free packing - for pipelines by diameter 125 mm and more. Under the squeezed conditions of packing in channels, it is possible to apply gasket compensators for pipelines by diameter from 100 mm and more, while with above-grade packing on low supports for pipelines by diameter from 250 mm and more.

The compensation for the thermal elongations of pipelines because of the use of rotations of route (auto/self-compensation) can be applied with all methods of the packing of thermal grid/networks independent of the diameters of pipelines and parameters of heat carrier at the value of angle to 150°. With the value of the angle of it is more than 150°, and also when according to

stress analysis rotation of pipelines it cannot be used for auto/self-compensation, pipelines at turning point fasten with fixed supports.

Page 183.

The dimensions of flexible compensators and reach of pipeline during auto/self-compensation calculate for compensation. Obtained by calculation for the compensation for reach are checked against the lateral thermal displacement of pipeline, which must be not more amount of looseness (taking into account reserve of approximately 50 mm) between the external surfaces of isolation/insulation or between the structure and the external surface of isolation/insulation. Maximum side mixing will be at the turning point of route.

10.3. Calculation of the flat/plane sections of Pipelines for the compensation for thermal elongations with flexible compensators and auto/self-compensations.

During the calculation of tubes for the compensation

for thermal elongations with flexible P- and S-shaped compensators or the sections of auto/self-compensation determine such dimensions by which the longitudinal bending compensating stresses, which appear during elastic deformation of tubes, do not exceed permissible.

The calculation of tubes for the compensation for thermal elongations produces with the "method of forces", in this case one of the fixed supports of the calculated section of the pipeline, included between two fixed supports, is considered unfastened. To the unfastened end of the pipeline, apply the reaction forces of elastic deformation and the bending moments, which replace the reject/thrown support (Fig. 10.10).

During the calculation of tubes for the compensation for thermal elongations, are accepted the following assumptions:

a) fixed supports are considered absolutely rigid;

b) the resistance of forces of friction of movable supports during the thermal elongation of pipeline is not considered.

The thermal elongations of the section of pipeline in reference direction x and y (Fig. 10.11) are determined from the formulas:

$$\Delta l_x = \alpha \Delta t\,(x_B - x_A)\ мм; \qquad (10.36)$$

$$\Delta l_y = \alpha \Delta t\,(y_B - y_A)\ мм, \qquad (10.37)$$

where α - the coefficient of linear expansion of carbon tube steels in mm/m deg (table 10.11);

Δt - a calculated difference in the temperatures in deg between the maximum temperature of heat carrier t and the calculated temperature of surrounding air for the planning of heating $t_{н.о}$;

$x_B; x_A$ - the coordinate of the ends of the calculated section of pipeline in points B and A along the axis x;

$y_B; y_A$ - also, along the axis y.

Complete thermal elongation determines by the geometric summation of thermal elongations in reference direction x and y:

$$\Delta l = \sqrt{\Delta l_x^2 + \Delta l_y^2}\ мм. \qquad (10.38)$$

For symmetrical relative to y axis of the sections of pipelines (for example, section of pipeline with U-shaped compensator) thermal elongation in the direction of y axis takes as equal to zero: $\Delta l_y = 0$. complete thermal elongation in this case is determined from the formula

$$\Delta l = \Delta l_x = \alpha \Delta t L \text{ мм}, \qquad (10.39)$$

where L is a distance between fixed supports in m.

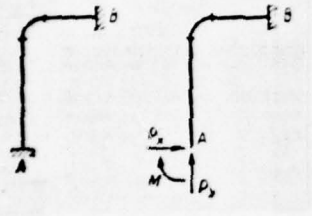


Fig 10.10

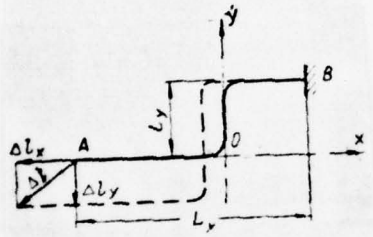


Fig 10.11

Fig. 10.10. Replacement on calculated section of pipeline AB of fixed support A by forces and torque/moment.

Fig. 10.11. Thermal elongations of section of pipeline AB.

Table 10.11. Modulus of elasticity and the coefficient of linear expansion for tube steels of brands 10, 15, 20, St. 2, St. 3, St. 4.

Температура стенки трубы в *град* (1)	Модуль упругости E в *кгс/см²* (2)	Коэффициент линейного расширения α в *мм/м град* (3)
20	$2.05 \cdot 10^6$	$1.18 \cdot 10^{-2}$
75	$1.99 \cdot 10^6$	$1.2 \cdot 10^{-2}$
100	$1.975 \cdot 10^6$	$1.22 \cdot 10^{-2}$
125	$1.95 \cdot 10^6$	$1.24 \cdot 10^{-2}$
150	$1.93 \cdot 10^6$	$1.25 \cdot 10^{-2}$
175	$1.915 \cdot 10^6$	$1.27 \cdot 10^{-2}$
200	$1.875 \cdot 10^6$	$1.28 \cdot 10^{-2}$
225	$1.847 \cdot 10^6$	$1.3 \cdot 10^{-2}$
250	$1.82 \cdot 10^6$	$1.31 \cdot 10^{-2}$
275	$1.79 \cdot 10^6$	$1.32 \cdot 10^{-2}$
300	$1.755 \cdot 10^6$	$1.34 \cdot 10^{-2}$
325	$1.727 \cdot 10^6$	$1.35 \cdot 10^{-2}$
350	$1.695 \cdot 10^6$	$1.36 \cdot 10^{-2}$
375	$1.665 \cdot 10^6$	$1.37 \cdot 10^{-2}$
400	$1.63 \cdot 10^6$	$1.38 \cdot 10^{-2}$
425	$1.60 \cdot 10^6$	$1.40 \cdot 10^{-2}$

Note. Table gives the average coefficient of the linear expansion of tube steels α during heating from 0 to t°C.

Key: (1). Temperature of the wall of tube in deg. (2). Modulus of elasticity E in kg/cm². (3). Coefficient of linear expansion α in mm/m deg.

A Calculated difference in the temperatures is determined from the formula

$$\Delta t = t - t_{u.o}\,^{\circ}C \qquad (10.40)$$

Each obtained formulas (10.36) and (10.37) sign characterizes the direction of movement of the unfastened end A of the designed section of pipeline. Positive sign corresponds to the positive direction of the thermal elongation of the left unfastened end of pipeline A which accepts opposite to positive reference direction in the reference system of coordinates, while sign "minus" corresponds to the negative direction of the thermal elongation of the unfastened end A which accepts opposite to negative reference direction (Fig. 10.12).

For decrease in the bending compensating stress in running order of pipeline for the sections of pipelines with flexible compensators, is produced the preliminary bracing of pipeline in cold state during installation.

The preliminary bracing of the sections of auto/self-compensation is provided for according to design considerations, if it is not possible to increase the length of the section of auto/self-compensation.

Preliminary bracing is produced in the size/dimension:

at the temperature of heat carrier to 400°C inclusively to 50o/o from the complete thermal elongation of the compensated for section of pipeline;

at the temperature of heat carrier higher 400°C by 100o/o of complete thermal elongation of the compensated for section of pipeline.

During for compensation, is considered not complete, but calculated thermal elongation.

The calculated thermal elongation of the compensated for section of pipeline is determined with consideration the coefficient ε which is introduced on the value of complete thermal elongation. Coefficient ε considers value of the preliminary bracing of compensators, possible inaccuracy in the calculation and relaxation of compensating stresses.

The calculated thermal elongations of the section of pipeline in the direction of x and y axes are determined from the formulas:

during the auto/self-compensation

$$\Delta x = \varepsilon \Delta l_x \text{ мм}; \quad (10.41)$$
$$\Delta y = \varepsilon \Delta l_y \text{ мм}; \quad (10.42)$$

with the flexible compensators

$$\Delta x = \varepsilon \Delta l \text{ мм}. \quad (10.43)$$

The values of coefficient ε are given in Table 10.12

During the determination of the calculated thermal elongation of the section of pipeline without preliminary bracing the coefficient ε in formulas (10.41)-(10.42) takes as equal to one.

The forces of elastic deformation, which appear in pipeline during the compensation for thermal elongation, are considered in the form of two comprising directed along the axes x and y and determine from the formulas:

$$P_x = \frac{\Delta x I_{y0} + \Delta y I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} EI \cdot 10^{-7} \text{ kgf} \quad (10.44)$$

$$P_y = \frac{\Delta y I_{x0} + \Delta x I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} EI \cdot 10^{-7} \text{ kgf} \quad (10.45)$$

where I is the moment of the inertia of the cross section of the wall of tube with nominal thickness of the wall of tube in cm⁴;

E - the modulus of elasticity of tube steel in kg/cm^2 (see Table 10.11);

I_{x0}, I_{y0} the central moments of the inertia of the reduced length of the centerline of pipeline in m^3;

I_{xy0} - the central product of inertia of the reduced length of the centerline of pipeline in m^3.

As the positive direction of forces, is accepted the direction, which coincides with positive reference direction, as negative - the direction, which coincides with negative reference direction.

Resultant force of elastic deformation, they determine from the formula

$$P = \sqrt{P_x^2 + P_y^2} \text{ kgf} \quad (10.46)$$

the bending moment from the forces of elastic deformation in any section/cut of the section of pipeline determines from the formula

$$M = (y - y_0) P_x - (x - x_0) P_y \text{ kgcm} \qquad (10.47)$$

where x, y - are coordinates of the section/cut of the section of pipeline in question in the reference system of coordinates in m;

x_0, y_0 - the coordinate of the elastic center of gravity of the designed section of pipeline in m.

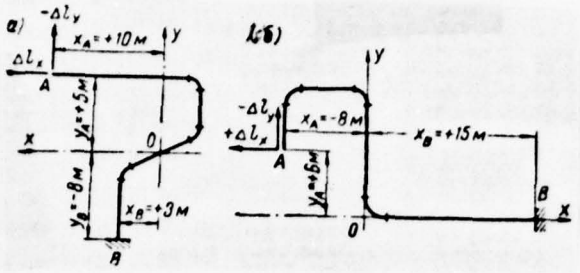


Fig. 10.12. Examples of determination of sign of thermal elongation of section of pipeline

а) $\Delta l_x = \alpha\Delta t\,(x_B - x_A) = \alpha\Delta t\,(3-10) = -7\alpha\Delta t$;

$\Delta l_y = \alpha\Delta t\,(y_B - y_A) = \alpha\Delta t\,[-8-(+5)] = -13\alpha\Delta t$;

б) $\Delta l_x = \alpha\Delta t\,(x_B - x_A) = \alpha\Delta t\,[15-(-8)] = 23\alpha\Delta t$;

$\Delta l_y = \alpha\Delta t\,(y_B - y_A) = \alpha\Delta t\,(0-6) = -6\alpha\Delta t$

Table 10.12. Coefficient ε

(1) Максимальная температура теплоносителя в *град*	(2) Предварительная растяжка компенсатора в %	(3) Для расчета труб	
		(4) на холодное состояние $\varepsilon_{хол}$	(5) на рабочее состояние $\varepsilon_{раб}$
$t<250$	50	0,5	0,5
$250\leqslant t<300$		0,6	
$300\leqslant t<400$		0,7	
$t\geqslant 400$	100	1	0,35

Key: (1). Maximum temperature of heat carrier in deg. (2). Preliminary bracing of compensator in o/o. (3). For the calculation of tubes. (4). to cold state. (5). to working order.

Page 185.

The obtained from formula (10.47) sign of torque/moment characterizes its direction. Positive sign corresponds to positive direction of the bending moments, as which is accepted the direction of rotation from the positive coordinate X-axis to the positive coordinate X-axis to the positive coordinate y axis; sign "minus" corresponds to negative direction of the bending moments, as which is accepted the direction of rotation from the positive y axis to the positive X-axis.

The section/cut of tube with the maximum bending moment can be determined either analytically by formula (10.47) by the comparison of the values of torque/moments for the different section/cuts of section of pipeline, or graphically by the construction of the diagram/curve of the bending moments (Fig. 10.13). For this, the forces of elastic deformation P_x and P_y are placed in the elastic center of gravity to scale of forces taking into account the obtained the calculation signs. By the construction of the parallelogram of forces are determined value and the

direction of resultant force of elastic deformation P. The force line of P can be examined as moment diagram. In this case the bending moment in any section/cut of pipeline with coordinates x, y determine from the formula

$$M = Ph_{xy} \text{ kgcm} \qquad (10.48)$$

where h_{xy} is the perpendicular, omitted from the section/cut of pipeline with coordinates x, y to the force line of P, in m.

The maximum bending moment will be in the section/cut for which value $h = h_{макс}$.

$$M_{макс} = Ph_{макс} \text{ kgcm} \qquad (10.49)$$

During the use of a graphic method after the determination of section/cut with maximum torque/moment the value of maximum torque/moment for the obtained section/cut is recommended the determining of from formula (10.47).

The bending compensating stresses on the direct/straight sections of pipelines in welded and sharply bent branch/removals determine from the formula

$$\sigma_{н}^{к} = \frac{M}{W} \text{ kgf/mm}^2 \qquad (10.50)$$

where W - the moment of resistance of the cross section of the wall of tube with the nominal wall thickness of tube in cm^3.

The bending compensating stresses in the bent smooth branch/removals are determined from the formula

$$\sigma_{н}^{к} = \frac{Mm}{W} \text{ kgf/mm}^2 \qquad (10.51)$$

where m is a coefficient of the concentration of the longitudinal bending stresses in branch/removals.

The values of the bending compensating stresses, obtained from formulas (10.50) and (10.51), must not exceed the permissible bending compensating stress, received from stress analysis.

Slenderness ratio for the bent smooth branch/removals is determined from the following formulas:

with $h \leq 1$ - by the formula of Clark and Reisner

$$k = \frac{1,65}{h}, \qquad (10.52)$$

where h is a geometric characteristic of the flexibility of tube;

with $h > 1$ - by the formula of the pocket

$$k = \frac{10 + 12h^2}{1 + 12h^2}. \qquad (10.53)$$

The geometric characteristic of the flexibility of tube is determined from the formula

$$h = \frac{sR}{r_{cp}^2}, \qquad (10.54)$$

where s is a nominal wall thickness of tube in mm;

r_{cp} - the mean radius of tube in mm;

R are a radius of the axle/axis of the bent tube or a conditional radius of welded branch/removal in mm.

The mean radius of tube is determined from the formula

$$r_{cp} = \frac{D_n - s}{2} \text{ MM}. \qquad (10.55)$$

The value of coefficient k can be determined by the

curve/graph of Fig. 10.14.

The coefficient of the concentration of the longitudinal bending of compensational stresses for the bent smooth branch/removals is determined from the formula

$$m = \frac{0,9}{h^{2/3}} \qquad (10.56)$$

or on the curve/graph of Fig. 10.14 consider only at values of m of large unity (with h < 0.85).

The characteristic of the bent smooth branch/removal for tubes on the "assortment of the tubes of thermal grid/networks" is given in Table 10.13.

The central and central products of inertia of the reduced length of the centerline of pipeline are determined according to the method of the "elastic center of gravity" relative to the axle/axes, passing through the elastic center of gravity of the designed section of pipeline.

For calculation they trace to scale the diagram of the section of pipeline on centerline, the section of pipeline divide/mark off into separate direct/straight and arc cuttings off (branches) will be applied the centers of

gravity of separate direct/straight and arc cuts, they select and will apply to diagram the reference system of coordinates.

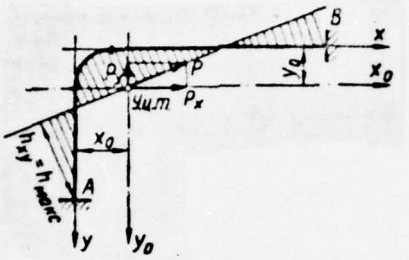


Fig. 10.13. Captura nott page.

Fig. 10.13. Diagram/curve of bending moments of L-shaped section of pipeline.

Page 186.

The origin of coordinates selects in such a way that the coordinate axes would be passed through the centers of gravity of the larger possible number of cuts, and for the symmetrical sections of pipeline of one of the coordinate axes, would be the axis of the symmetry of section. The coordinate axis one should select parallel or coinciding with basic linear segments of figure.

Positive reference direction is selected so that the large part of the section of pipeline would be furnished in positive fourth. Examples of the selection of the coordinate axes of line in Fig. 10.15.

For determining the central and central products of inertia of the section of pipeline relative to the

axle/axes, passing through the elastic center of gravity, first of all calculate the moments of inertia and the products of inertia of the section of pipeline of the relatively reference system of coordinates, and then correct for the translation of axes to the elastic center of gravity.

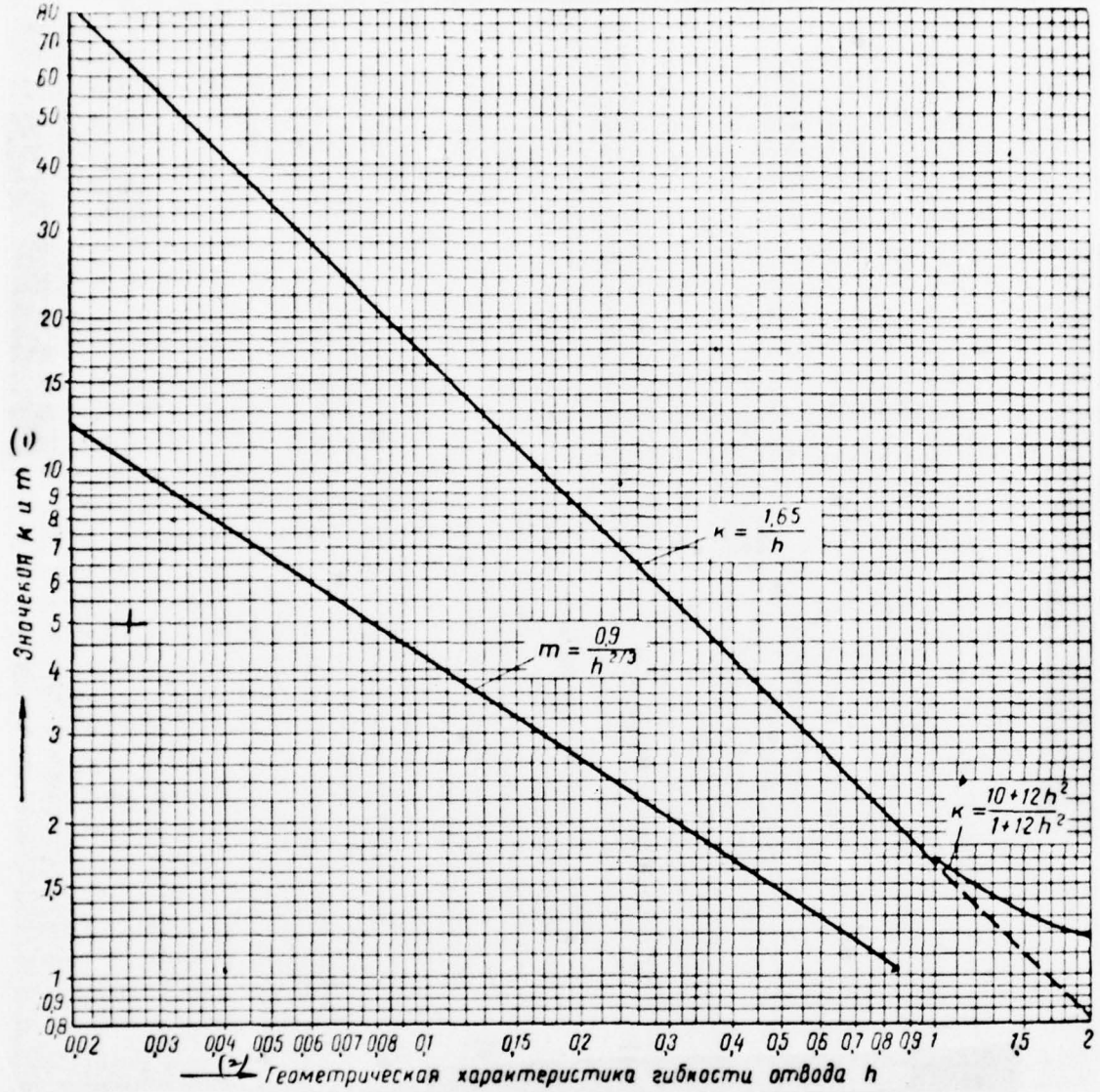


Fig. 10.14. Graph for determining slenderness ratio of branch/removal k and of coefficient of concentration of longitudinal bending stresses in branch/removals m.

Key: (1). Valuesof k and m. (2). Geometric characteristic of flexibility of branch h.

Page 187.

The moments of the inertia of the section of the pipeline of the relatively reference system of coordinates are determined from the formulas:

$$I_x = \Sigma I'_x + \Sigma S_x y_c = \Sigma I'_x + \Sigma l_{np} y_c^2 \text{ м}^3; \quad (10.57)$$

$$I_y = \Sigma I'_y + \Sigma S_y x_c = \Sigma I'_y + \Sigma l_{np} x_c^2 \text{ м}^3, \quad (10.58)$$

where $\Sigma I'_x$ and $\Sigma I'_y$ - the sum of the intrinsic moments of the inertia of cuts of м^3;

S_x and S_y - the static moments of inertia of м^2;

l_{np} - the reduced length of the centerline of the cut of pipeline m;

x_c, y_c - the coordinate of the centers of gravity of the cuts of pipelines of the reference system of coordinates in m.

The product of inertia of the section of the pipeline

of the relatively reference system of coordinates is determined from the formula

$$I_{xy} = \Sigma I'_{xy} \pm \Sigma S_y y_c = \Sigma I'_{xy} \pm \Sigma l_{np} x_c y_c \text{ м}^3, \quad (10.59)$$

where $\Sigma I'_{xy}$ is a sum of its own products of inertia of cuts in m³.

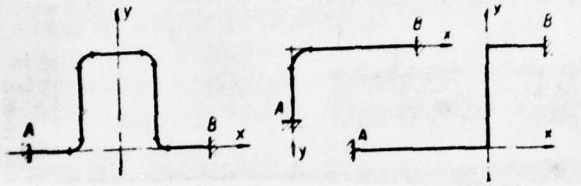


Fig. 10.15. Examples of selection of coordinate axes for different calculated sections of pipelines.

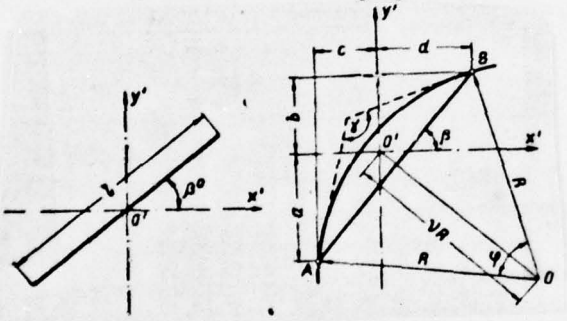


Fig 10.16

Fig. 10.17.

Fig. 10.16. Position of linear segment relative to axle/axes, passing through its own center of gravity.

Fig. 10.17. Position of arc cut relative to axle/axes, passing through its own center of gravity.

Table 10.13. Characteristic of the bent smooth branch/removal.

Условный проход D_y в мм (11)	Наружный диаметр $D_н$ в мм (2)	Толщина стенки (номинальная) $s_{от}$ в мм (3)	Радиус оси R в мм (4)	Средний радиус $r_{ср}$ в мм (5)	Геометрическая характеристика гибкости h (6)	Коэффициент гибкости k (7)	Коэффициент концентрации продольных напряжений изгибающих компенсационных напряжений m (8)
25	32	2,5	150	14,75	1,72	1,245	—
32	38	2,5	151	17,75	1,19	1,5	—
40	45	2,5	200	21,25	1,11	1,56	—
50	57	3,5	200	26,75	0,978	1,69	—
70	76	3,5	350	36,25	0,933	1,77	—
80	89	3,5	350	42,75	0,671	2,46	1,172
100	108	4	500	52	0,74	2,23	1,1
125	133	4	500	64,5	0,482	3,42	1,465
150	159	4,5	600	77,25	0,451	3,66	2,38
175	194	5	700	94,5	0,392	4,23	1,68
		7		93,5	0,56	2,947	1,32
200	219	6	850	106,5	0,45	3,67	1,53
		7		106	0,53	3,11	1,37
250	273	7	1000	133	0,396	4,17	1,67
		8		132,5	0,457	3,61	1,51
300	325	8	1200	158,5	0,383	4,3	1,71
		9		158	0,433	3,81	1,57
350	377	9	1500	184	0,4	4,13	1,66
		10		183,5	0,445	3,7	1,55
400	426	9	1700	208,5	0,353	4,67	1,81
		11		207,5	0,435	3,8	1,57

Key: (1). The internal diameter in mm. (2). Outside diameter h mm. (3). Thickness of wall (is nominal) in mm. (4). Radius of axle/axis R in mm. (5). The mean radius in mm. (6). Geometric characteristic of flexibility. (7). Slenderness ratio k. (8). Coefficient of the concentration of the longitudinal bending compensating stresses m.

Page 188.

Their own and their own products of inertia of cuts relative to axle/axes x' and y', passing through their own centers of gravity of cuts (Fig. 10.16 and 10.17), parallel and equally directed to the taken reference axes of coordinates, are determined from the formulas:

$$I'_x = \frac{\sin^2\beta}{12} l^3 = c_x l^3 M^2; \qquad (10.60)$$

for linear segments:

$$I'_y = \frac{\cos^2\beta}{12} l^3 = c_y l^3 M^2; \qquad (10.61)$$

$$I'_{xy} = \pm \frac{\sin\beta\cos\beta}{12} l^3 = \pm c_{xy} l^3 M^2; \qquad (10.62)$$

for the arc cuts:

$$I'_x = c_{x1} kR^3 M^3; \quad (10.63)$$

$$I'_y = c_{y1} kR^3 M^3; \quad (10.64)$$

$$I'_{xy} = \pm c_{xy1} kR^3 M^3, \quad (10.65)$$

where β is angle of the slope of linear segment to axle/axis x' in deg.

Coefficients for the computation of their own and their own products of inertia of cuts relative to axle/axes x' and y'. c_x, c_y, c_{x1}, c_{y1}, c_{xy} and c_{xy1} are given in table 10.14 and 10.15.

Table 10.14. Coefficients for the calculation of linear segments.

(1) Угол наклона прямого отрезка к оси x' β°	(2) Коэффициенты для вычисления		
	(3) собственных моментов инерции		(4) собственных центробежных моментов инерции
	c_x	c_y	c_{xy}
0; 180	0	0,0833	0
15; 165	0,00558	0,0777	0,0208
30; 150	0,0208	0,0625	0,036
45; 135	0,0417	0,0417	0,0417
60; 120	0,0625	0,0208	0,036
75; 105	0,0777	0,00558	0,0208
90	0,0833	0	0

Key: (1). Angle of the slope of linear segment to axle/axis. (2). Coefficients for computation. (3). The intrinsic moments of inertia. (4). its own products of inertia.

Table 10.15. Coefficients for the calculation of arc cuts.

Угол (1)			Коэффициенты для вычисления (2)								
(3) поворота трассы γ°	(4) дугового отрезка $\varphi^\circ = 180 - \gamma$	(5) наклона хорды дугового отрезка к оси x' β°	(6) расстояния от центра тяжести до центра кривизны	(7) приведенной длины	(8) расстояний от концов дугового отрезка A и B до центра тяжести дугового отрезка $0'$				(9) собственных моментов инерции		(10) собственных центробежных моментов инерции
			ν	$c_{пр}$	c_a	c_b	c_c	c_d	c_{x1}	c_{y1}	c_{xy1}
150	30	0; 180	0,989	0,524	0,023	0,023	0,259	0,259	0,012	0	0
		15; 165			0,069	0,045	0,244	0,256	0,011	0,001	0,003
		30; 150			0,139	0,109	0,1	0,227	0,009	0,003	0,005
		45; 135			0,198	0,166	0,166	0,198	0,006	0,006	0,006
135	45	0; 180	0,974	0,785	0,05	0,05	0,383	0,383	0,039	0	0
		15; 165			0,147	0,051	0,357	0,383	0,037	0,003	0,01
		30; 150			0,245	0,148	0,307	0,357	0,029	0,010	0,017
		45; 135			0,305	0,235	0,235	0,305	0,02	0,020	0,019
120	60	0; 180	0,955	1,047	0,089	0,089	0,5	0,5	0,091	0,002	0
		15; 165			0,215	0,043	0,459	0,507	0,085	0,008	0,022
		30; 150			0,327	0,178	0,389	0,448	0,068	0,024	0,038
		45; 135			0,417	0,291	0,291	0,417	0,046	0,046	0,044
105	75	0; 180	0,93	1,309	0,137	0,137	0,609	0,609	0,172	0,005	0
		15; 165			0,289	0,028	0,563	0,613	0,16	0,016	0,042
		30; 150			0,422	0,186	0,459	0,583	0,13	0,047	0,072
		45; 135			0,528	0,334	0,334	0,528	0,088	0,088	0,083
90	90	0; 180	0,9	1,571	0,193	0,193	0,707	0,707	0,285	0,012	0
		15; 165			0,361	0,011	0,632	0,732	0,267	0,031	0,068
		30; 150			0,521	0,187	0,53	0,694	0,217	0,080	0,118
		45; 135			0,636	0,364	0,364	0,636	0,149	0,149	0,137

Key: (1). Angle. (2). Coefficients for computation. (3). the rotation of route. (4). arc cut. (5). the slope/inclination of the chord of arc cut to axle/axis. (6). distance from the center of gravity to center of curvature. (7). given length. (8). distances from the ends of the arc cut A and B to the center gravity of arc cut 0'. (9). the intrinsic moments of inertia. (10). Natural products of inertia.

Page 189.

Their own axle/axes of the arc and direct cuts x' and y' must be equally directed and are parallel to coordinate axes. The intrinsic moments of inertia I'_x and I'_y are always positive.

For determining the sign of their own product of inertia of direct or arc cut (Fig. 10.18) one should through the origin of coordinates "0" conduct the imaginary line, Parallel line cut or the chord of arc cut.

If the imaginary line traverses fourths with identical signs - its own product of inertia will be positive, if through fourths with different signs - negative.

The intrinsic moment of the inertia of linear segment of the relatively its own axle/axis, parallel to initial coordinate axis, is equal to zero.

Its own product of inertia of linear segment, parallel to one of the coordinate axes, or the arc cut whose chord is parallel to one of the coordinate axes, is equal to zero.

The static moments of inertia of cuts are determined from the formulas:

$$S_x = \pm l_{mp} y_c m^3; \quad (10.66)$$
$$S_y = \pm l_{mp} x_c m^3. \quad (10.67)$$

The sign of the static moment of inertia determines by the sign of the coordinates of the center of gravity of cut.

The reduced length of the centerline of the cut of pipeline is determined from the formulas:

for linear segments

$$l_{mp} = l m; \quad (10.68)$$

for the arc cuts

$$l_{mp} = \frac{\varphi}{57,3} kR = c_{mp} kR m. \quad (10.69)$$

where l — is geometric length of cut into m;

φ - the angle of arc cut in deg;

φ_{ap} - is a coefficient for the computation of the length of arc cut (table 10.15);

R - a radius of the axle/axis of the bent tube or conditional radius of welded branch/removal in m.

In such a case, when the calculated section of pipeline consists of cuts with the different rigidity of tube (different diameters, the thicknesses of walls, the quality of material), the identical rigidity of the larger number of cuts are accepted as the calculated EI, a reduced length of the remaining cuts, which have another rigidity $E'I'$ determine from the formulas:

for linear segments

$$l_{ap} = l\frac{EI}{E'I'} \text{ m}; \qquad (10.70)$$

for the arc cuts

$$l_{ap} = \frac{\varphi}{57.3} kR\frac{EI}{E'I'} \text{ m}. \qquad (10.71)$$

During coordinate determination of the centers of gravity of cuts, one should consider that the center of

gravity of linear segment is located in the middle of linear segment, and the center of gravity of arc cut - on bisector of the angle, tightened by arc, at a distance from the center of arc 0, equal to vR (see Fig. 10.17).

Distance from the center of gravity of arc 0' to center of curvature 0 according to bisector is determined from the formula

$$vR = \frac{2\sin\varphi/2}{\varphi} R \text{ м}. \qquad (10.72)$$

Distances of the center of gravity of arc 0' are determined from the formulas:

$$a = \left[\sin\frac{\varphi}{2}\sin\beta + \right.$$
$$\left. + \left(v - \cos\frac{\varphi}{2}\right)\cos\beta\right] R = c_a R \text{ м}; \qquad (10.73)$$
$$b = \left[\sin\frac{\varphi}{2}\sin\beta - \right.$$
$$\left. - \left(v - \cos\frac{\varphi}{2}\right)\cos\beta\right] R = c_b R \text{ м}; \qquad (10.74)$$
$$c = \left[\sin\frac{\varphi}{2}\cos\beta - \right.$$
$$\left. - \left(v - \cos\frac{\varphi}{2}\right)\sin\beta\right] R = c_c R \text{ м}; \qquad (10.75)$$
$$d = \left[\sin\frac{\varphi}{2}\cos\beta + \right.$$
$$\left. + \left(v - \cos\frac{\varphi}{2}\right)\sin\beta\right] R = c_d R \text{ м}. \qquad (10.76)$$

The values of coefficients v, c_a, c_b, c_c, c_d are given in table 10.15.

The central and central products of inertia of section relative to the axle/axes, passing through the elastic center of gravity of the centerline of section with coordinates x_0 and y_0, are determined from the formulas:

$$I_{x0} = I_x - L_{sp} y_0^2 \text{ м}^3; \quad (10.77)$$

$$I_{y0} = I_y - L_{sp} x_0^2 \text{ м}^3; \quad (10.78)$$

$$I_{xy0} = I_{xy} - L_{sp} x_0 y_0 \text{ м}^3, \quad (10.79)$$

where $L_{sp} y_0^2, L_{sp} x_0^2, L_{sp} x_0 y_0$ — corrections for the transfer of coordinate axes from the initial origin of coordinates to the elastic center of gravity in м^3;

L_{sp} — the reduced length of the centerline of the section of pipeline in m;

x_0, y_0 - the coordinate of the elastic center of gravity of the relatively selected system in m.

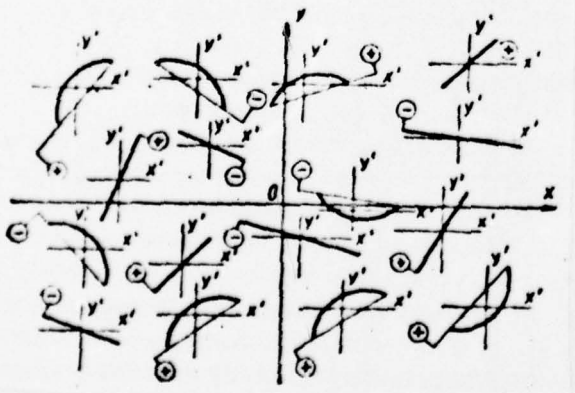


Fig 10,18. Examples of determining the sign of centrifugal moments of inertia of straight and arc segments.

Table 10.16. Example of the calculation of section pipeline for the compensation for thermal elongations.

Элемент расчета (1)	Единица измерения (2)	Расчетные формулы и обозначения (3)	Результаты расчета (4)
1	2	3	4
Максимальная температура теплоносителя (5)	град (6)	t	300
Условный проход (7)	мм (8)	D_y	300
Наружный диаметр трубы (9)	"	$D_н$	325
Номинальная толщина стенки трубы (10)	"	s	8
Материал стенки трубы (11)	—	Сталь марки (12)	10
Расстояние между неподвижными опорами (13)	м	L	27.3
Расчетная температура наружного воздуха для проектирования отопления (14)	град (6)	$t_{н.о}$	−30
Вылеты компенсатора (15)	м	H_1	7.4
		H_2	4.4
Спинка компенсатора (16)	"	B	16.9
Прочие геометрические размеры компенсатора (17)	"	l_1	5
		l_2	5
		l_3	14.5
		l_4	2
		l_5	3
Внутренний диаметр трубы (18)	мм (8)	$D_в = D_н - 2s$	309
Момент инерции поперечного сечения стенки трубы (19)	$см^4$ (20)	$I = \frac{\pi}{64}(D_н^4 - D_в^4)$	10010
Момент сопротивления поперечного сечения стенки трубы (21)	$см^3$ (20)	$W = \frac{\pi}{32}\frac{(D_н^4 - D_в^4)}{D_н} = \frac{2I}{D_н}$	616
Радиус оси гнутой трубы (22)	мм (8)	R	1200
Средний радиус трубы (23)	"	$r_{ср} = \frac{D_н - s}{2}$	156.5
Геометрическая характеристика гибкости гнутого гладкого отвода (24)	—	$h = \frac{sR}{r_{ср}^2}$	0.383
Коэффициент гибкости гнутого гладкого отвода (25)	—	$k = \frac{1.65}{h}$	4.3
Коэффициент концентрации продольных изгибающих компенсационных напряжений в гнутом гладком отводе (26)	—	$m = \frac{0.9}{h^{2/3}}$	1.71

Key: (1). Cell/element of calculation. (2). Unit of measurement. (3). Calculation formulas and designations. (4). Results of calculation. (5). Maximum temperature of heat carrier. (6). deg. (7). The internal diameter. (8). mm. (9). Outside diameter of tube. (10). Nominal wall thickness of tube. (11). the material of the wall of tube. (12). Steel of mark/brand. (13). Distance between fixed supports. (14). The calculated temperature of surrounding air for the planning of heating. (15). Flights of compensator. (16). Back of compensator. (17). Other geometric dimensions of compensator. (18). Tube bore. (19). Moment of the inertia of the transverse section/cut of the wall of tube. (20). cm^4. (21). Moment of resistance of the cross section of the wall of tube. (22). Radius of the axle/axis of the bent tube. (23). The mean radius of tube. (24). Geometric characteristic of the flexibility of the bent smooth branch/removal. (25). Slenderness ratio of the bent smooth branch/removal. (26). Coefficient of the concentration of the longitudinal bending compensating stresses in the bent smooth branch/removal.

Continuation table 10.16.

Элемент расчета (1)	Единица измерения (2)	Расчетные формулы и обозначения (3)	Результаты расчета (4)
1	2	3	4
Угол дугового отрезка (27)	—	$\varphi°$	90°
Угол наклона хорды дугового отрезка к оси x' для l_2 и l_4 (28)	—	$\beta°$	45°
То же, для l_6 и l_8 (29)			135°
Коэффициенты для вычисления расстояний от концов дугового отрезка до центра тяжести дугового отрезка (30)	—	$c_b = c_c = \left[\sin\frac{\varphi}{2}\cos\beta - \left(\nu - \cos\frac{\varphi}{2}\right)\sin\beta\right]$	0,354
		$c_a = c_d = \left[\sin\frac{\varphi}{2}\cos\beta + \left(\nu - \cos\frac{\varphi}{2}\right)\sin\beta\right]$	0,636
Расстояния от концов дугового отрезка до центра тяжести дугового отрезка (31)	м	$b = c = c_b R = c_c R$	0,437
		$a = d = c_a R = c_d R$	0,783
Коэффициент для вычисления приведенной длины дугового отрезка (32)	—	$c_{пр} = 0{,}0174\varphi$	1,571
Приведенная длина дугового отрезка $l = l_1 = l_3 = l_5 = l_7$ (33)	м	$l_{пр} = c_{пр} kR$	0,1
Центральные моменты инерции участка относительно осей x_0, y_0 (34)	м⁴	I_{x0} (по табл. 10.18)	490,4
		I_{y0} (по табл. 10.18)	4156,7
Центральный центробежный момент инерции относительно осей x_0, y_0 (35)	"	I_{xy0} (по табл. 10.18)	—490,7
Модуль упругости трубной стали 10 при температуре $t = 300$° С (36) (37)	кгс/см²	E	$1{,}755 \cdot 10^6$
Коэффициент линейного расширения трубной стали при температуре $t = 300$° С (38)	мм/м·град (39)	α	$1{,}34 \cdot 10^{-2}$
Расчетное тепловое удлинение конца A трубопровода: по оси x (40)	мм	$\Delta x = \alpha L (t - t_{н.о})$	121
То же, по оси y (41)		$\Delta y = -\alpha (H_1 - H_2)(t - t_{н.о})$	—13,3
Сила упругой деформации по оси x (42)	кгс (43)	$P_x = \frac{\Delta x' I_{y0} + \Delta y I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} \cdot \frac{EI}{10^7}$	497
То же, по оси y (41)	"	$P_y = \frac{\Delta y I_{x0} + \Delta x I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} \cdot \frac{EI}{10^7}$	64,5
Равнодействующая сил упругой деформации (44)	"	$P = \sqrt{P_x^2 + P_y^2}$	501,2
Изгибающий момент в точке C (45)	кгсм (43)	$M_C = -P_x y_0 + P_y (x_0 - R)$ или $M_C = -P h_c$	—1702

Page 191.

Continuation table 10.16.

Key: (27). Angle of arc cut. (28). Angle of the slope of the chord of arc cut to axle/axis x' for l_2 and l_4 (29) The same, for l_4 and l_4 (30). Coefficients for the computation of distances from the ends of the cut to the center of gravity of arc cut. (31). Distances from the ends of the arc cut to the center of gravity of arc cut. (32). Coefficient for the computation of the reduced length of arc cut. (33). The reduced length of arc cut (34). The central moments of the inertia of section relative to axle/axes x_0, y_0. (35). Central product of inertia relative to axle/axes x_0, y_0. (36). Modulus of elasticity of tube steel 10 at temperature of t = 300 C. (37). kgf/cm³. (38). The coefficient of the linear expansio of tubes ache steel at temperature of t = 300 C. (39). mm/m•deg. (40). Calculated thermal elongation of end A of the pipeline: along the axis x. (41). The same, along the axis y. (42). force of elastic deformation along the axis x. (43). kgf. (44). Resultant force of elastic deformation. (45). Bending moment at point C.

continuation table 10.16.

Элемент расчета (1)	Единица измерения (2)	Расчетные формулы и обозначения (3)	Результаты расчета (4)
1	2	3	4
Изгибающий момент в точке D (46)	кгсм (43)	$M_D = P_x(H_1 - y_0) + P_y(x_0 + R)$ или $M_D = Ph_D$	1763
Максимальное продольное изгибающее компенсационное напряжение в точке D (47)	кгс/мм² (37)	$\sigma^{\text{к}}_{\text{и}(D)} = \frac{M_D m}{W}$	4.9

Notes. 1 calculation is made on the assumptions that the end of pipeline A is unfastened.

2. Sign "minus" at bending moment at point C shows only direction of this torque/moment and during determinatic of stresses it is not considered.

3. Obtained calculation for compensation maximum each compensating stress must not be more than permissible compensating stress, determined by stress analysis.

Key: (46). Bending moment at point D. (47). Maximum longitudinal bending compensating stress at point D.

The reduced length of the centerline of the section of pipeline is determined from the formula

$$L_{пр} = \Sigma l_{пр} \text{ м}. \qquad (10.80)$$

The coordinates of the elastic center of gravity of the relatively selected system are determined from the formulas:

$$x_0 = \frac{\Sigma S_y}{L_{пр}} \text{ м}, \qquad (10.81)$$

$$y_0 = \frac{\Sigma S_x}{L_{пр}} \text{ м}. \qquad (10.82)$$

Central product of inertia for the figures of symmetrical relative to one of the coordinate axes is equal to zero.

Employing aforementioned procedure is made an example of calculation for the compensation for the thermal elongations of table 10.16-10.18 for the section of the pipeline whose diagram is given in Fig. 10.19.

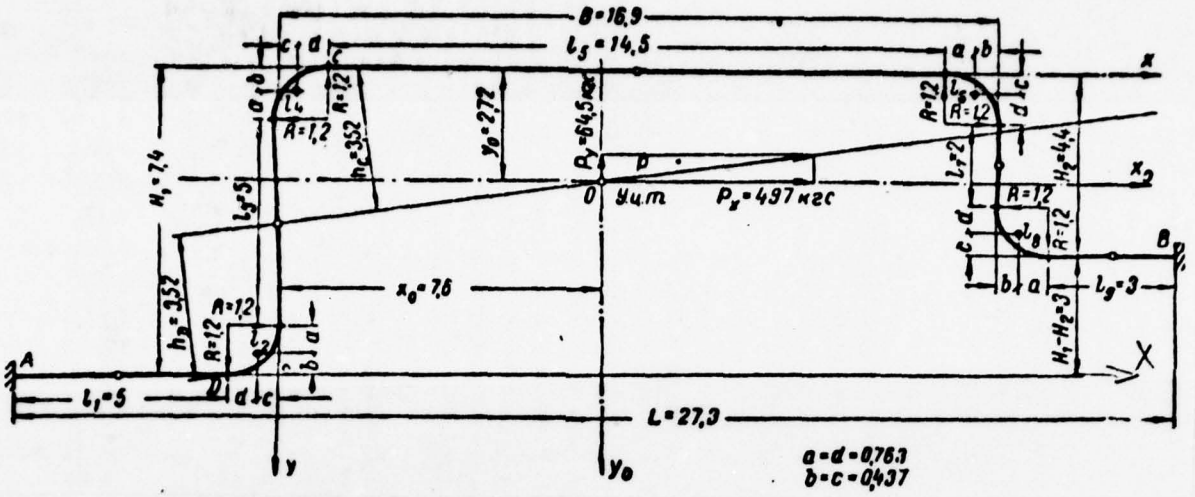


Fig. 10.19. Diagram of calculated section of pipeline on centerline.

Page 193. Table 10.17. Determination of its own and its own products of inertia.

Отрезки (1)	Геометрическая длина отрезков l или радиус оси отвода R в м (2)	Коэффициент для вычисления собственных моментов инерции (3) c_x / c_{x1}	c_y / c_{y1}	c_{xy} / c_{xy1}	Коэффициент гибкости гнутого гладкого отвода k (4)	(5) l^0 или kR^1 в м³	Собственные и собственные центробежные моменты инерции в м⁵ (6) $I'_x = c_x l^0$ или $I'_x = c_{x1} kR^2$ (6)	$I'_y = c_y l^0$ (5) или $I'_y = c_{y1} kR^2$	$I'_{xy} = c_{xy} l^0$ или $I'_{xy} = c_{xy1} kR^2$ (5)
l_1	5	0	0,0833	0	1	125	0	10,41	0
l_2	1,2	0,149	0,149	0,137	4,3	7,43	1,11	1,1	−1,02
l_3	5	0,0833	0	0	1	125	10,41	0	0
l_4	1,2	0,149	0,149	0,137	4,3	7,43	1,11	1,11	−1,02
l_5	11,5	0	0,0833	0	1	3049	0	254	0
l_6	1,2	0,149	0,149	0,137	4,3	7,43	1,11	1,11	1,02
l_7	2	0,0833	0	0	1	8	0,67	0	0
l_8	1,2	0,149	0,149	0,137	4,3	7,43	1,11	1,11	1,02
l_9	3	0	0,0833	0	1	27	0	2,25	0
Сумма собственных моментов инерции (7)							$\Sigma I'_x = 15,82$	$\Sigma I'_y = 271,1$	$\Sigma I'_{xy} = 0$

Key: (1). Cuts. (2). Geometric length of cuts l or a radius of the axle/axis of branch/removal R in m. (3). Coefficient for the computation of the intrinsic moments of inertia. (4). Slenderness ratio of the bent smooth branch/removal. (5). or. (6). Its own and its own products of inertia in m³. (7). Sum the intrinsic moments of inertia.

Table 10.18. Determination of the central moments of inertia.

Отрезки (1)	Приведенная длина отрезков $l_{пр}$ в м (2)	Координаты центра тяжести отрезков в м (3)		Статические моменты отрезков в м³ (4)		$S_x y_c$	$S_y x_c$	$S_x x_c - S_y y_c$
		y_c	x_c	$S_x = l_{пр} y_c$	$S_y = l_{пр} x_c$			
l_1	5	7.4	−3.7	37	−18.5	273.8	68.5	−136.9
l_2	8.1	6.96	−0.44	56.4	−3.6	392.5	1.6	− 24.8
l_3	5	3.7	0	18.5	0	68.5	0	0
l_4	8.1	0.44	0.44	3.6	3.6	1.6	1.6	1.6
l_5	14.5	0	8.45	0	122.5	0	1035.1	0
l_6	8.1	0.44	16.46	3.6	133.3	1.6	2194.1	59.3
l_7	2	2.2	16.9	4.4	33.8	9.7	571.2	74.4
l_8	8.1	3.96	17.34	32.1	140.5	127.1	2436.3	556.6
l_9	3	4.4	19.6	13.2	58.8	58.1	1152.5	258.7
	$L_{пр} = \Sigma l_{пр} = 61.9$	$y_c = \frac{S_x}{L_{пр}} = 2.72$	$x_c = \frac{S_y}{L_{пр}} = 7.6$	$\Sigma S_x = 168.8$	$\Sigma S_y = 470.4$	$\Sigma S_x y_c = 982.9$	$\Sigma S_y x_c = 7460.9$	$\Sigma S_x x_c = \Sigma S_y y_c = 788.9$
Сумма собственных моментов инерции (по табл. 10.17) (5)						$\Sigma I'_x = 15.82$	$\Sigma I'_y = 271.1$	$\Sigma I'_{xy} = 0$
Моменты инерции участка относительно осей x, y (6)						$I_x = 946.4$	$I_y = 7732$	$I_{xy} = 788.9$
Поправка на перенос осей в упругий центр тяжести (7)						$-L_{пр} y_0^2 = -468$	$-L_{пр} x_0^2 = -3575.3$	$-L_{пр} x_0 y_0 = -1279.6$
Центральные моменты инерции участка относительно осей x_0, y_0 (8)						$I_{x_0} = 488.4$	$I_{y_0} = 4156.7$	$I_{x_0 y_0} = -490.7$

Key: (1). Cuts. (2). The reduced length of cuts $l_{пр}$ in m. (3). Coordinates of the center of gravity of cuts in m. (4). The static moments of cuts into m². (5). Sum the intrinsic moments of inertia (on table 10.17). (6). Moments of the inertia of section relative to X-axes, y. (7). Correction for the translation of axes to the elastic center of gravity. (8). The central moments of the inertia

of section relative to axle/axes x_0, y_0.

Page 194.

10.4. Calculation for the compensation for the thermal elongations of the flat/plane sections of the pipelines of different configuration.

For simplification in the calculations for the compensation for the thermal elongations of pipelines, are given below calculated formulas for determining the forces of elastic deformation and bending longitudinal compensating stresses for some circuits of the sections of pipelines natural compensation (auto/self-compensation), of the meeting during the planning thermal grid/networks. Formulas are derived by the given above procedure of calculation of tubes for the compensation for thermal elongations.

Calculation formulas are given for the conditions of the calculation of the sections of pipeline taking into account and without taking into account of the flexibility

of branch/removals. The flexibility of branch/removal is considered for the sections of pipelines with bent smooth branches with the short adjacent to branch/removal arms. Coefficients k and m in this case are determined from formulas (10.52) - (10.56).

during the calculation of the sections of pipelines with welded and sharply bent branch/removals, and also during the calculation of the sections of pipelines with the bent smooth branch/removals with the long adjacent to branch/removal arms the flexibility of branch/removals is not considered. Coefficients k and m in this case accept equal to unity.

In the given below formulas are accepted the following designations:

α - a coefficient of the linear expansion of tube steel in mm/m deg;

E - modulus of elasticity of tube steel in kg/cm^2;

I - the moment of the inertia of the cross section of the wall of tube in cm^3;

Δt - a calculated difference in the temperatures between the maximum temperature of heat carrier t and the calculated for the planning of heating temperature of surrounding air $t_{н.в}$ in deg;

l (with indices) - length of linear segments of pipes in m;

R - a radius of the axle/axis of branch/removal in m.

$D_н$ - a outside diameter of tube in cm.

L-shaped section of pipeline with angle of rotation 90° (taking into account the flexibility of branch/removal).

The diagram of calculated section is given in Fig. 10.20.

Calculation is performed by the formulas:

the reduced length of the centerline of the section of the pipeline

$$L_{np} = l_1 + l_2 + 1{,}57Rk \text{ м}. \qquad (10.83)$$

the coordinate of the elastic center of gravity:

$$x_0 = \frac{l_2(0{,}5l_2 + R) + 0{,}57R^2k}{L_{np}} \text{ м}, \qquad (10.84)$$

$$y_0 = \frac{l_1(0{,}5l_1 + R) + 0{,}57R^2k}{L_{np}} \text{ м}; \qquad (10.85)$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x0} = l_1\left(\frac{l_1^2}{3} + l_1R + R^2\right) + 0{,}355R^3k - L_{np}y_0^2 \text{ м}^3; \qquad (10.86)$$

$$I_{y0} = l_2\left(\frac{l_2^2}{3} + l_2R + R^2\right) + 0{,}355R^3k - L_{np}x_0^2 \text{ м}^3; \qquad (10.87)$$

central product of inertia relative to axle/axes x_0 and y_0

$$I_{xy0} = 0{,}072R^3k - L_{np}x_0y_0 \text{ м}^3; \qquad (10.88)$$

calculated thermal elongations along X-axes and y:

$$\Delta x = \alpha\Delta t(l_2 + R) \text{ мм}; \qquad (10.89)$$

$$\Delta y = -\alpha\Delta t(l_1 + R) \text{ мм}. \qquad (10.90)$$

The forces of elastic deformation are determined from formulas (10.44) and (10.45).

Maximum bending torque/moment on linear segment:

when $l_1 < l_2$ at point A

$$M_{макс} = (l_1 + R - y_0) P_x + x_0 P_y \text{ кгсм}; \quad (10.91)$$

when $l_1 > l_2$ at point B

$$M_{макс} = -(l_2 + R - x_0) P_y - y_0 P_x \text{ кгсм}; \quad (10.92)$$

the maximum bending moment on the bent cut at point (middle of arc)

$$M = -(y_0 - 0.293R) P_x + (x_0 - 0.293R) P_y \text{ кгсм}. \quad (10.93)$$

The bending compensating stresses are determined from formulas (10.50) and (10.51).

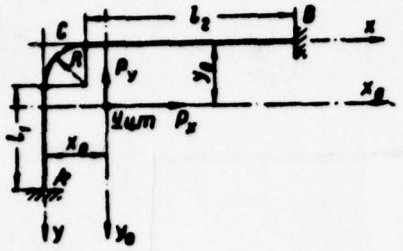


Fig. 10.20. L-shaped section of pipeline with angle of rotation 90° (taking into account flexibility of branch/removal).

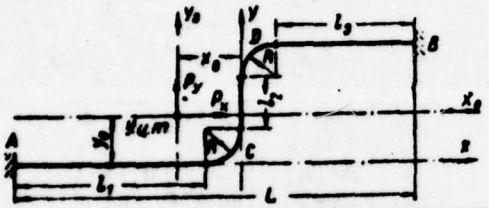


Fig. 10.21. Z-shaped section of pipeline (taking into account flexibility of branch/removals).

Z-shaped section of pipeline (taking into account the

flexibility of branch/removals).

The diagram of calculated section is given in Fig. 10.21.

Calculation is performed by the formulas:

the reduced length of the centerline of the section of the pipeline

$$L_{np} = l_1 + l_2 + l_3 + 3{,}14Rk \text{ м}; \quad (10.94)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{l_2(0{,}5l_2 + R) - l_1(0{,}5l_1 + R)}{L_{np}} \text{ м}; \quad (10.95)$$

$$y_0 = \frac{(l_2 + 2R)(l_2 + 0{,}5l_3 + 1{,}57Rk)}{L_{np}} \text{ м}; \quad (10.96)$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x0} = \frac{l_2^3}{12} + \left(l_2 + \frac{l_2}{4}\right)(l_2 + 2R)^2 + 1{,}57Rk\left(l_2^2 + 3{,}272l_2R + 3R^2\right) - L_{np}y_0^2 \text{ м}^3; \quad (10.97)$$

$$I_{y0} = \frac{l_3^3 + l_1^3}{12} + l_1(0{,}5l_1 + R)^2 + l_3(0{,}5l_3 + R)^2 + 0{,}713R^2k - L_{np}x_0^2 \text{ м}^3; \quad (10.98)$$

central product of inertia relative to axle/axes x_0 and y_0:

$$I_{x_0y_0} = l_3 + 0{,}5(l_2 + R)(l_2 + 2R) + R^2k + \\ + 0{,}57R^2l_2k - L_{пр}r_0y_0 \text{ м}^4; \quad (10.99)$$

calculated thermal elongations along X-axes and y:

$$\Delta x = \alpha\Delta t L \text{ мм}. \quad (10.100)$$

$$\Delta y = \alpha\Delta t (l_2 + 2R) \text{ мм} \quad (10.101)$$

The forces of elastic deformation are determined from formulas (10.44) and (10.45).

The maximum bending moment is greatest of the torque/moments the specific on linear segments for points A and B on bent cuts for point C and D (middle of arc):

$$M_A = (l_1 + R + x_0)P_y - y_0P_x \text{ кгсм}; \quad (10.102)$$

$$M_B = (l_3 + 2R - y_0)P_x - \\ - (l_2 + R - x_0)P_y \text{ кгсм}; \quad (10.103)$$

$$M_C = (x_0 + 0{,}293R)P_y - \\ - (y_0 - 0{,}293R)P_x \text{ кгсм}; \quad (10.104)$$

$$M_D = (x_0 - 0{,}293R)P_y + \\ + (l_3 + 1{,}707R - y_0)P_x \text{ кгсм}. \quad (10.105)$$

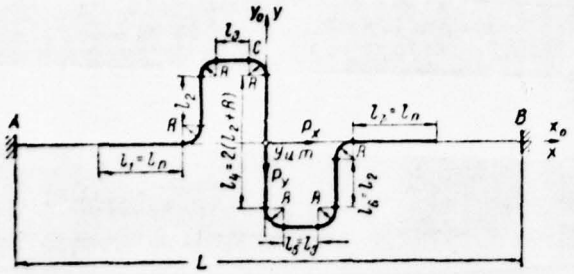


Fig. 10.22. Section of pipeline with s-shaped compensator (taking into account the flexibility of branch/removals).

The bending compensating stresses are determined from formulas (10.50) and (10.51).

Section of pipeline with S-shaped compensator (taking into account the flexibility of branch/removals).

The diagram of calculated section is given in Fig. 10.22.

Calculation is performed by the formulas:

the coordinate elastic-g of the center of gravity: $x_0 = 0$; $y_0 = 0$ central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x0} = \frac{l_2^3}{6} + \frac{2}{3}(l_0 + R)^3 + 2\left(l_0 + \frac{l_0}{4}\right)(l_0 + 2R)^3 + 6{,}28Rk\left(l_2^2 + 3{,}27l_2 R + 2{,}9R^2\right) м^3; \quad (10.106)$$

$$I_{y0} = \frac{l_1^3 + l_3^3}{6} + 2l_1\left(\frac{l_1}{2} + l_0 + 3R\right)^2 + \left(2l_0 + \frac{l_0}{2}\right)(l_0 + 2R)^2 + 6{,}28Rk\left(l_3^2 + 4l_3^2 R + 4{,}34R^2\right) м^3; \quad (10.107)$$

central product of inertia relative to axle/axes x_0 and y_0:

$$J_{xy0} = -(0{,}5l_0l_0 + l_0R + l_0R + 2R^2) \times (2l_2 + 2l_0 + 6{,}28Rk) - 0{,}142R^3k \; м^3; \quad (10.108)$$

calculated thermal elongations along X-axes and y:

$$\Delta y = 0;$$
$$\Delta x = \alpha_{ст} \Delta t L \; мм; \quad (10.109)$$

The force of elastic deformation:

$$P_x = \frac{\Delta x I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} \cdot \frac{EI}{10^7} \; кгс; \quad (10.110)$$

$$P_y = \frac{\Delta x I_{xy0}}{I_{x0} I_{y0} - I_{xy0}^2} \cdot \frac{EI}{10^7} \; кгс; \quad (10.111)$$

Key: (1). kgf.

the maximum bending moment at point C

$$M_{изг.с} = (l_0 + 2R) P_x + P_y R \; кгс.м. \quad (10.112)$$

The bending compensating stresses are determined from formulas (10.50) and (10.51).

In the absence of direct/straight insets on the back of S-shaped compensator ($l_4=l_5=0$) formulas are simplified and take form (when $l_1=nR$ and $l_3=mR$):

the coordinates of the elastic center of gravity:

$$x_0=0;\ y_0=0;$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x_0}=0{,}67R^3+18{,}1\,kR^3+4mR^3+20{,}5mR^2k+$$
$$+6{,}28m^2R^2k+4m^2R^3+1{,}3m^2R^3\mu^2;\quad(10.113)$$
$$I_{y_0}=27{,}2kR^3+8mR^3+6m^2R^3+0{,}66m^2R^3\mu^2;\quad(10.114)$$

central product of inertia relative to axle/axes x_0, y_0

$$I_{x_0y_0}=-6{,}28mR^2k-12{,}7R^2k-$$
$$-4mR^2-2m^2R^2\mu^2.\qquad(10.115)$$

Calculated thermal elongations, the forces of elastic deformation, the maximum bending moment and the compensating stress at point C are determined from formulas (10.109) - (10.112), (10.50) and (10.51).

In the absence of direct/straight insets on back ($l_3=l_4=0$) and in flight ($l_4=l_4=0$) S-shaped compensator calculation can be performed directly by the formulas:

The force of elastic deformation:

$$P_x = \frac{\Delta xEI}{0{,}67R^3(1+27k)10^7} \text{ кгс}; \quad (10.116)$$

$$P_y = \frac{-\Delta xEI}{26{,}8R^3\left(76+k+\frac{2{,}8}{k}\right)10^7} \text{ кгс}; \quad (10.117)$$

the maximum bending compensating stress

$$\sigma_u^x = \frac{(2P_xR-P_yR)m}{W} \text{ кгс/мм}^2. \quad (10.118)$$

Section of pipeline with S-shaped compensator (without taking into account of the flexibility of branch/removals).

The diagram of calculated section is given in Fig. 10.23.

Calculation is performed by the formulas: the coordinates of the elastic center of gravity: $x_0 = 0$; $y_0 = 0$; the central moments of inertia relative to axle/axes x_0 and y_0

$$I_{x_0} = \frac{5}{6} l_2^3 + 2l_2^2\left(l_0 + \frac{l_2}{4}\right) \mu^2; \quad (10.119)$$

$$I_{y_0} = \frac{l_1^3 + l_3^3}{6} + 2l_1\left(\frac{l_1}{2} + l_0\right)^2 + l_3^2\left(2l_0 + \frac{l_3}{2}\right) \mu^2; \quad (10.120)$$

central product of inertia relative to axle/axes x_0 and y_0:

$$I_{xy_0} = -l_0 l_3 (l_0 + l_0) \mu^2. \quad (10.121)$$

calculated thermal elongations and the forces of elastic deformation are determined from formulas (10.109) - (10.111)

The maximum bending moment on the back of compensator is determined from the formula

$$M_{изг} = l_0 P_x \text{ изг.} \quad (10.122)$$

The bending compensating stresses are determined from formula (10.50).

the figurative section of pipeline (taking into account the flexibility of branch/removals).

The diagram of calculated section is given in Fig. 10.24 calculation is performed by the formulas:

the reduced length of the centerline of the section of the pipeline

$$L_{np} = l_1 + l_2 + l_3 + l_4 + 4{,}71Rk \text{ м}; \quad (10.123)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{(l_2 + 2R)(l_3 + 0{,}5l_2) + l_4(0{,}5l_4 + l_3 + 3R) + \ldots}{L_{np}} \ldots + \frac{+ 3{,}14Rk\,(l_2 + 2{,}18R)}{L_{np}} \text{ м}; \quad (10.124)$$

$$y_0 = \frac{(l_3 + 2R)(l_2 + 0{,}5l_3) + (l_3 + R - 0{,}5l_1)\,l_1 + \ldots}{L_{np}} \ldots + \frac{+ 3{,}14Rk\,(l_3 + 1{,}81R)}{L_{np}} \text{ м}; \quad (10.125)$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x0} = \frac{l_1^3 + l_3^3}{12} + \left(l_0 + \frac{l_0}{4}\right)(l_0 + 2R)^2 + \\ + \left(l_3 + R - \frac{l_1}{2}\right)^2 l_1 + 3,14Rk\left(l_3^2 + 3,27Rl_3 + \right. \\ \left. + 2,69R^2\right) - L_{sp}\, y_0^2\, M^2; \qquad (10.126)$$

$$I_{y0} = \frac{l_2^3 + l_4^3}{12} + \left(l_0 + \frac{l_0}{4}\right)(l_0 + 2R)^2 + \\ + l_4\left(l_0 + 3R + \frac{l_4}{2}\right)^2 + \\ + 3,14Rk\left(l_2^2 + 4Rl_2 + 4,33R^2\right) - L_{sp}\, x_0^2\, M^2; \qquad (10.127)$$

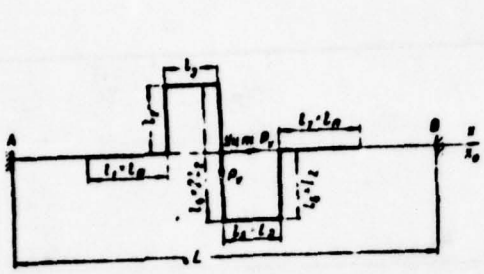
central product of inertia relative to axle/axes x_0 and y_0:

$$I_{xy0} = 0,5\left(l_3 + 2R\right)\left(l_2 + 2R\right)\left(l_3 + l_5\right)^2 + \\ + 3,14Rk\left(0,5l_2l_3 + Rl_2 + Rl_3 + 2,02R^2\right) - \\ - L_{sp}\, x_0 y_0\, M^2; \qquad (10.128)$$

calculated thermal elongations along X-axes and y: are according to formula (10.100)

$$\Delta y = \alpha\Delta t\,(l_1 - R - l_3)\ \text{M.M.} \qquad (10.129)$$

The forces of elastic deformation are determined from formulas (10.44) and (10.45).



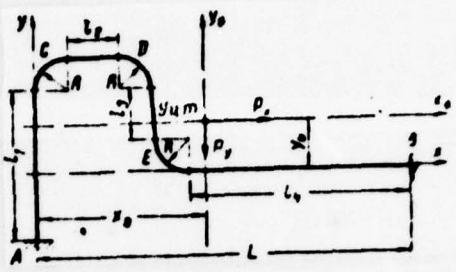


Fig. 10.24.

Fig. 10.23. Section of pipeline with S-shaped compensator (without taking into account of flexibility of branch/removals).

Fig. 10.24.  is section of pipeline (taking into account flexibility of branch/removals).

Page 197.

The maximum bending moment is greatest of the torque/moments, determined on linear segments for points A and B and on bent cuts for points C, D and E (middle of arc):

$$M_A = (l_3 + R - y_0 - l_1) P_x + x_0 P_y \text{ кгсм}; \quad (10.130)$$

$$M_B = -y_0 P_x - (l_4 + l_2 + 3R - x_0) P_y \text{ кгсм}; \quad (10.131)$$

$$M_C = (l_3 + 1{,}707R - y_0) P_x - (0{,}293R - x_0) P_y \text{ кгсм}; \quad (10.132)$$

$$M_D = (l_3 + 1{,}707R - y_0) P_x - (l_2 + 1{,}707R - x_0) P_y \text{ кгсм}; \quad (10.133)$$

$$M_E = (0{,}293R - y_0) P_x - (l_2 + 2{,}293R - x_0) P_y \text{ кгсм}. \quad (10.134)$$

The bending compensating stresses are determined from formulas (10.50) and (10.51).

The figurative section of pipeline (without taking into account of the flexibility of branch/removals).

The diagram of calculated section is given in Fig. 10.25. Calculation is performed by the formulas: the reduced length of the centerline of the section

$$L_{np} = l_1 + l_2 + l_3 + l_4 \text{ м}; \qquad (10.135)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{0,5(l_3 + l_4)^2 + l_2 l_3}{L_{np}} \text{ м}; \qquad (10.136)$$

$$y_0 = \frac{0,5l_3^2 + l_2 l_3 + l_1 l_3 - 0,5l_1^2}{L_{np}} \text{ м}; \qquad (10.137)$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x_0} = \frac{l_1^3 + l_3^3}{3} + l_2^2 (l_1 + l_2) - \\ - l_1^2 l_3 - L_{np} y_0^2 \ m^3; \quad (10.138)$$

$$I_{y_0} = \frac{l_2^3 + l_4^3}{3} + l_2^2 (l_3 + l_4) + \\ + l_2 l_4^2 - L_{np} x_0^2 \ m^3; \quad (10.139)$$

central product of inertia relative to axle/axes x_0 and y_0

$$I_{x_0 y_0} = 0.5 l_2 l_3 (l_2 + l_3) - L_{np} x_0 y_0 \ m^3; \quad (10.140)$$

calculated thermal elongations along X-axes and y:

Δx by formula (10.100).

$$\Delta y = \alpha \Delta t (l_1 - l_3) \ mm. \quad (10.141)$$

The forces of elastic deformation are determined by formulas (10.44) and (10.45).

Maximum the bending moment will be maximum from obtained the formulas:

$$M_A = (l_3 - y_0 - l_1) P_x + x_0 P_y \text{ кгсм}; \quad (10.142)$$
$$M_B = -y_0 P_x - (l_4 + l_3 - x_0) P_y \text{ кгсм}; \quad (10.143)$$
$$M_C = (l_3 - y_0) P_x + x_0 P_y \text{ кгсм}; \quad (10.144)$$
$$M_D = (l_3 - y_0) P_x - (l_3 - x_0) P_y \text{ кгсм}; \quad (10.145)$$
$$M_E = -y_0 P_x - (l_3 - x_0) P_y \text{ кгсм}. \quad (10.146)$$

The bending compensating stresses are determined from formula (10.50).

When $l_1 = l_3$ the formulas take the form:

the reduced length of the centerline of the section

$$L_{np} = l_3 + 2l_3 \text{ м}; \quad (10.147)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{0{,}5\,(l_3 + l_4)^2\, l_2 l_3}{L_{sp}}\ \text{мм}; \qquad (10.148)$$

$$y_0 = \frac{l_3\,(l_2 + l_3)}{L_{sp}}\ \text{мм}; \qquad (10.149)$$

the central moments of inertia relative to axle/axes x_0, y_0:

$$I_{x_0} = l_3^2\left(l_3 + \frac{2}{3}\,l_3\right) - L_{sp}\,y_0^2\ \text{мм}^4; \qquad (10.150)$$

I_{y_0} — by formula (10.139).

Central product of inertia relative to axle/axes x_0, y_0 is determined from formula (10.140).

Calculated thermal elongations along X-axes, y:

$$\Delta x = \alpha \Delta t\,(l_3 + l_4)\ \text{мм}; \qquad (10.151)$$
$$\Delta y = 0.$$

The forces of elastic deformation the maximum bending moment and the bending compensating stresses are determined from formulas (10.44), (10.45), (10.142) - (10.146) and (10.50).

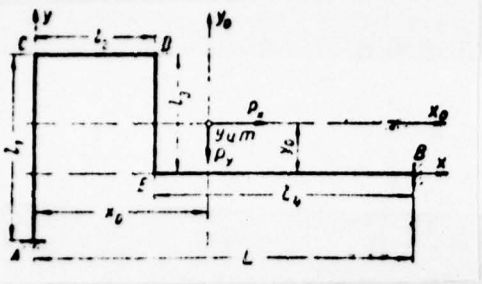
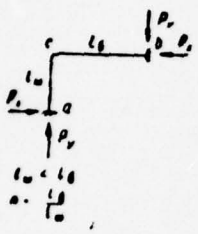
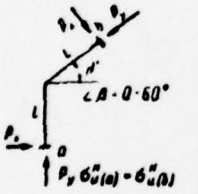
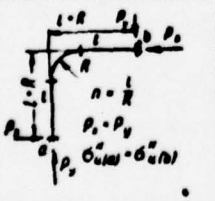
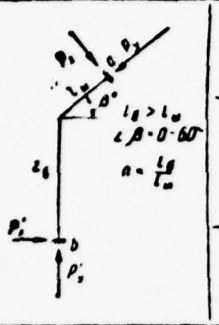
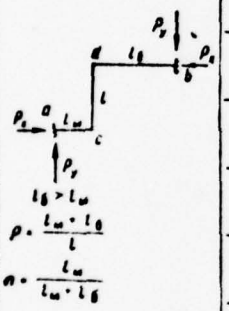
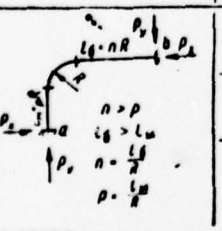


Fig. 10. section of pipeline (without taking into account of flexibility of branch/resovals).

Table 10.19. Calculation formulas for determination P_z, P_y, $\sigma^{н}_{н}$ и and dimensionless coefficients A, B and C for the sections of the pipelines of different configuration.

(1) № схем	Схема расчетного участка (2)	Формулы для определения (3) P_z, P_y и $\sigma^{н}_{н}$	Формулы для определения (3) коэффициентов A, B и C (4)	№ рисунков номограмм для определения коэффициентов A, B, C (5)
1		$P_z = A\frac{\alpha EI\Delta t}{10^7 l_м^2}$ кгс	$A = \frac{3(n^4+4n^3+3)}{n(n+1)}$	10.26
		$P_y = B\frac{\alpha EI\Delta t}{10^7 l_м^2}$ кгс	$B = \frac{3(3n^3+4n+1)}{n^3(n+1)}$	
		$\sigma^{н}_{н(a)} = C_{(a)}\frac{\alpha ED_н\Delta t}{10^7 l_м}$ $\frac{кгс}{мм^2}$ $\sigma^{н}_{н(b)} = C_{(b)}\frac{\alpha ED_н\Delta t}{10^7 l_м}$ $\frac{кгс}{мм^2}$ $\sigma^{н}_{н(c)} = C_{(c)}\frac{\alpha ED_н\Delta t}{10^7 l_м}$ $\frac{кгс}{мм^2}$	$C_{(a)} = \frac{1.5(n^4+2n^3+1)}{n(n+1)}$ $C_{(b)} = \frac{1.5(n^4+2n+1)}{n^3(n+1)}$ $C_{(c)} = \frac{3(n^3+1)}{n(n+1)}$	10.26
2		$P_z = A\frac{\alpha EI\Delta t}{10^7 l^2}$ кгс	$A = \frac{12(1+\sin\beta)}{\cos\beta}$	10.27
		$P_y = B\frac{\alpha EI\Delta t}{10^7 l^2}$ кгс	$B = \frac{12(1+\sin\beta)^2}{\cos^2\beta}$	
		$\sigma^{н}_{н(a)} = C\frac{\alpha ED_н\Delta t}{10^7 l}$ $\frac{кгс}{мм^2}$	$C = \frac{3(1+\sin\beta)}{\cos\beta}$	10.28
3		$P_z = A\frac{\alpha EI\Delta t}{10^7 R^2}$ кгс	$A = \frac{6(n+1)(1.57k+2n)}{n^4+k(3.14n^3+3.58n^2+0.64n)+0.1k^2}$	10.29
		$\sigma^{н}_{н(a)} = C\frac{\alpha ED_н\Delta t}{10^7 R}$ $\frac{кгс}{мм^2}$	$C = \frac{3(n+1)(n^2+k(1.57n+0.43))}{n^4+k(3.14n^3+2.58n^2+0.64n)+0.1k^2}$	
4	(6) См. схему 4 на стр. 199	$P'_z = A'\frac{\alpha EI\Delta t}{10^7 l_м^2}$ кгс	$A' = \frac{3[(3n^4+4n+1)+\sin\beta(7n^3+n)]}{n^3(1+n)\cos\beta}$	10.28
		$P'_y = B'\frac{\alpha EI\Delta t}{10^7 l_м^2}$ кгс	$B' = \frac{3[n^3(n^3+4n^2+3)+\sin^2\beta(7n^3+n)+}{n^3(1+n)\cos^2\beta}$ $-\frac{+\sin\beta(n^4+10n^2+4n+1)]}{n^3(1+n)\cos^2\beta}$	

Continuation Table 10.19.

№ схем (1)	Схема расчетного участка (1)	Формулы для определения (3): P_x, P_y и $\sigma^{к}_{м}$	Формулы для определения (4): коэффициентов A, B и C	№ рисунков номограмм для определения коэффициентов A, B, C (5)
4		$P_x = A \frac{\alpha E I \Delta t}{10^7 l_м^2}$ кгс	$A = \frac{3[(n^3+4n^2+3)+\sin\beta(n^2+7n)]}{n(1+n)\cos\beta}$	10.31
		$P_y = B \frac{\alpha E I \Delta t}{10^7 l_м^2}$ кгс	$B = \frac{3[(3n^3+4n+1)+n^2\sin^2\beta(n^2+7n)+}{n^2\cos^2\beta(1+n)} \rightarrow$ $\rightarrow \frac{+n\sin\beta(n^4+4n^2+10n+1)]}{n^2\cos^2\beta(1+n)}$	
		$\sigma^{к}_{м(a)} = C \frac{\alpha E D_м \Delta t}{10^7 l_м}$ кгс/мм²	$C = \frac{1.5(n^2+2n^2+1)}{n(n+1)\cos\beta} + \frac{1.5(n+3)}{(n+1)}\operatorname{tg}\beta$	10.32
5		$P_x = A \frac{\alpha E I \Delta t}{10^7 l^2}$ кгс	$A = \frac{3[p^3+4p^2+3-6n(1-n)(2p^2-p+1)]}{p(1+p)(1-3n+3n^2)(1+3pn-3pn^2)}$	10.33
		$P_y = B \frac{\alpha E I \Delta t}{10^7 l^2}$ кгс	$B = \frac{3[3p^2+4p+1+6np^2(1-n)(2-p+p^2)]}{p^2(1+p)(1-3n+3n^2)(1+3pn-3pn^2)}$	
		$\sigma^{к}_{м(a)} = C_{(a)} \frac{\alpha E D_м \Delta t}{10^7 2l}$ кгс/мм²	$C_{(a)} = \frac{2pn+p^2}{2(1+p)} B - \frac{1+2p-2pn}{2(1+p)} A$	$C_{макс}$ по рис. 10.34
		$\sigma^{к}_{м(c)} = C_{(c)} \frac{\alpha E D_м \Delta t}{10^7 2l}$ кгс/мм²	$C_{(c)} = \frac{p^2-2p^2n}{2(1+p)} B - \frac{1+2p-2pn}{2(1+p)} A$	
		$\sigma^{к}_{м(d)} = C_{(d)} \frac{\alpha E D_м \Delta t}{10^7 2l}$ кгс/мм²	$C_{(d)} = \frac{1+2pn}{2(1+p)} A + \frac{p^2-2p^2n}{2(1+p)} B$	
		$\sigma_{м(b)} = C_{(b)} \frac{\alpha E D_м \Delta t}{10^7 2l}$ кгс/мм²	$C_{(b)} = \frac{1+2pn}{2(1+p)} A - \frac{p^2+2p-2pn}{2(1+p)} B$	
6		$P_x = A \frac{\alpha E I \Delta t}{10^7 R^2}$ кгс	A° и B°°	10.35
		$P_y = B \frac{\alpha E I \Delta t}{10^7 R^2}$ кгс		
		$\sigma^{к}_{м(a)} = C \frac{\alpha E D_н \Delta t}{10^7 R}$ кгс/мм²	C°°°	10.36

° $A = \frac{(n+1)\left[\frac{n^3}{3}+n^2+n+0.355k-\frac{(0.5n^2+n+0.57k)^2}{n+p+1.57k}\right]+(p+1)\left[\frac{(0.5n^2+n+0.57k)(0.5p^2+p+0.57k)}{n+p+1.57k}-0.074\right]}{\left[\frac{n^3}{3}+n^2+n+0.355k-\frac{(0.5n^2+n+0.57k)^2}{n+p+1.57k}\right]\left[\frac{p^3}{3}+p^2+p+0.355k\frac{(0.5p^2+p+0.57k)^2}{n+p+1.57k}\right]-\left[0.07k-\frac{(0.5n^2+n+0.57k)(0.5p^2+p+0.57k)}{n+p+1.57k}\right]^2}$

°° $B = \frac{(p+1)\left[\frac{p^3}{3}+p^2+p+0.355k-\frac{(0.5p^2+p+0.57k)^2}{n+p+1.57k}\right]+(n+1)\left[\frac{(0.5n^2+n+0.57k)(0.5p^2+p+0.57k)}{n+p+1.57k}-0.07k\right]}{\left[\frac{n^3}{3}+n^2+n+0.355-\frac{(0.5n^2+n+0.57k)^2}{n+p+1.57k}\right]\left[\frac{p^3}{3}+p^2+p+0.355k-\frac{(0.5p^2+p+0.57k)}{n+p+1.57k}\right]-\left[0.07k-\frac{(0.5n^2+n+0.57k)(0.5p^2+p+0.57k)}{n+p+1.57k}\right]^2}$

°°° $C = \left[A\left(p+1-\frac{0.5p^2+p+0.57k}{n+p+1.57k}\right)-B\frac{0.5n^2+n+0.57k}{n+p+1.57k}\right]0.5.$

Key: (1). diagrams. (2). Diagram of calculated section. (3) Formulas for determination. (4). coefficients. (5). Figures of nomograms for determining the coefficients of A, B, C. (6). See diagram 4 on page 199.

Page 199.

Continuation table 10.19.

Notes. 1. Coefficients $c_{(a)}, c_{(b)}, c_{(c)}, c_{(d)}$ during their calculation in formulas for circuit 5 can be obtained with positive signs or "minus". During determination σ_n^x the sign of coefficients is not considered.

2. Formulas for circuits 1, 2, 4, 5 are given without taking into account of flexibility of branch/removals, and for circuits 3 and 6 - taking into account flexibility of branch/removals.

Key: (1). Diagrams. (2). Diagram of calculated section. (3) Formulas for determination. (4). Coefficients. (5). the figures of nomograms for determining the coefficients of A, B, C.

Page 200.

For most frequently met in practice of the planning of the thermal grid/networks of the configurations of the sections of pipelines (g-and-Z-figurative sections of pipelines) the simplified formulas for determining the forces of elastic deformation (P_x и P_y) and the bending longitudinal compensating stresses σ_n^x, expressed through dimensionless

coefficients of A, B, C, are given in table 10.19. For determining the dimensionless coefficients, are constructed nomograms (Fig. 10.26-10.36).

Tables 10.20 and 10.21, gives the auxiliary values: $\frac{\alpha EI}{10^7}$; $\frac{\alpha ED_н}{10^7}$, $\frac{\alpha EI}{R^2 \cdot 10^7}$; $\frac{\alpha ED_н}{R \cdot 10^7}$, entering the calculation formulas table 10.19.

During compilation table 10.20 and 10.21 product Accepted equal to $2.4 \cdot 10^4$ to kgf•mm/cm²•m•deg.

In the practice of the planning of thermal grid/networks, frequently appears the need of determining the lengths of the mutualling compensate arms of the L-shaped sections of the pipelines (see diagram 4 in table 10.20) which are determined (without taking into account of the flexibility of branch/removal) by the formulas:

the smaller compensating arm

$$l_м = l_{мм} \Delta l \text{ м}, \qquad (10.152)$$

of the larger compensating arm

$$l_б = n l_м \text{ м}, \qquad (10.153)$$

where $l_{мм}$ - is length of the smaller compensating arm in m,

referred to 1° C of a calculated difference in the temperatures, is determined according to nomograms of Figs. 10.37 and 10.38;

Δt - a calculated difference in the temperatures between the temperature of heat carrier t and the calculated temperature of surrounding air for heating t_{H--} in deg;

n - the relationship/ratio of arms.

Table 10.20. Auxiliary values for computation P_x, P_y and σ_u^M during the calculation of tubes taking into account the flexibility of branch/removals.

Наружный диаметр трубы $D_н$ в см (1)	Толщина стенки трубы s в мм (2)	Радиус оси гнутой трубы R в м (3)	$\frac{\pi EI}{10^2 R^2}$ в кгс/град (4)	$\frac{\pi ED_н}{10^2 R}$ в кгс/см² град (4)
3,2	2,5	0,15	0,271	0,0512
3,8	2,5	0,15	0,47	0,0608
4,5	2,5	0,2	0,454	0,054
5,7	3,5	0,2	1,27	0,0685
7,6	3,5	0,35	1,03	0,0521
8,9	3,5	0,35	1,69	0,0611
10,8	4	0,5	1,7	0,0518
13,3	4	0,5	3,24	0,0638
15,9	4,5	0,6	4,35	0,0636
19,4	5	0,7	6,5	0,0665
21,9	6	0,85	7,57	0,0618
27,3	7	1	12,4	0,0635
32,5	8 / 9	1,2	16,7 / 18,6	0,065
37,7	9 / 10	1,5	18,8 / 20,4	0,0604
42,6	9 / 11	1,7	21,3 / 25,7	0,0601

Key: (1). Outside diameter of tube $D_м$ in cm. (2). The wall thickness of pipe s in mm. (3). Radius of the axle/axis of the bent tube R in m. (4). kgf/deg.

Table 10.21. Auxiliary values for computation P_x, P_y and z_M^* during the calculation of tubes without taking into account of the flexibility of branch/removals.

Наружный диаметр трубы $D_н$ в см (1)	Толщина стенки трубы s в мм (2)	$aED_н$ в $\frac{кг}{10^4 кгс/мм^2 \cdot град}$ (3)	aEJ в $\frac{кг \cdot см^2}{10^4 кгс/мм^2 \cdot град}$ (4)	Наружный диаметр трубы $D_н$ в см (1)	Толщина стенки трубы s в мм (2)	$aEJ_н$ в $\frac{кг}{10^4 кгс/мм^2 \cdot град}$ (3)	aEJ в $\frac{кг \cdot см^2}{10^4 кгс/мм^2 \cdot град}$ (4)
3,2	2,5	0,00708	0,0061	52,9	8	0,127	106,7
3,8	2,5	0,00912	0,0106		9		119,3
4,5	2,5	0,0108	0,0181		10		131,8
5,7	3,5	0,0137	0,0508	63	6	0,151	137,4
7,6	3,5	0,0182	0,126		7		159,5
8,9	3,5	0,0214	0,206		8		181,7
10,8	4	0,0259	0,425		9		203,8
13,3	4	0,0319	0,809		10		224,7
15,9	4,5	0,0382	1,38	72	7	0,173	239
19,4	5	0,0466	3,16		8		272,2
21,9	6	0,0526	5,47		9		305
27,3	7	0,0655	12,4		10		337,4
32,5	8	0,078	24,0		11		369,6
	9		26,6		12		401,5
37,7	9	0,0905	42,3	82	7	0,197	354,5
	10		46,6		8		403,7
42,6	5	0,103	35,2		9		452,6
	6		41,9		10		501,1
	7		48,5		11		532,3
	8		55,1		12		596,9
	9		61,6	92	7	0,221	502,1
	10		67,9		8		572
	11		74,2		9		641,5
	12		80,3		10		710,4
	13		86,4		11		779
					12		847
47,8	5	0,115	49,0	102	8	0,245	781,5
	6		59,5		9		877
	7		69,9		10		971,4
	8		78,3		11		1065,1
52,9	6	0,127	59,9		12		1154,7
	7		69,9				

Key: (1). Outside diameter of tube D_M in cm. (2). The wall thickness of tube in mm. (3). kg·m/mm²·deg. (4). in kg·cm²/deg.

Page 201.

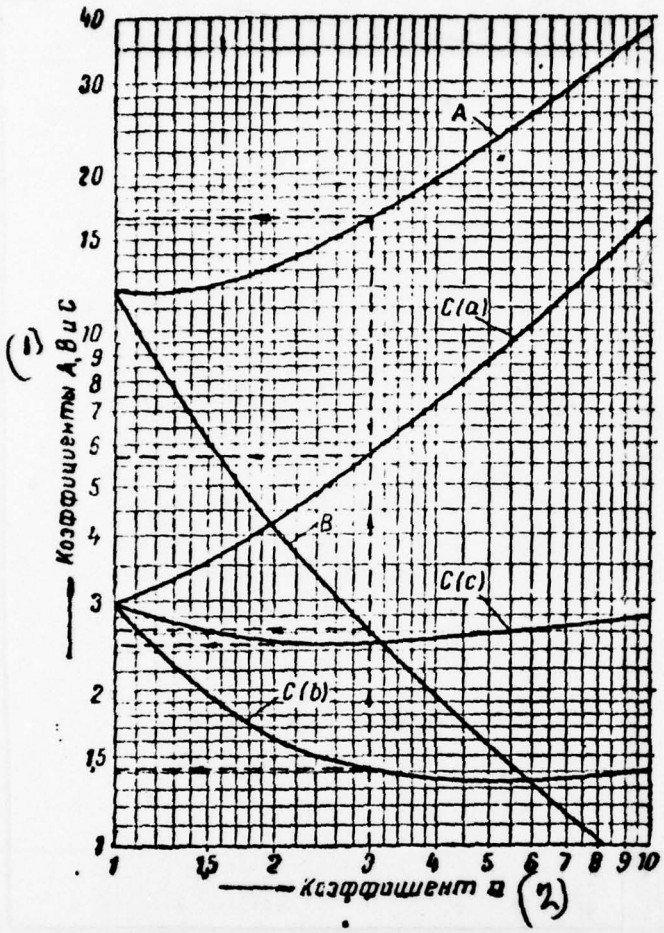


Fig. 10.26. Nomogram for determining dimensionless coefficients of A, B, C $_{(a),C(b),C(c)}$ for calculation of L-shaped section of pipeline with angle of rotation 90° without taking into account of flexibility of branch/removal.

Key: (1). Coefficients A, B, C. (2). Coefficient. D

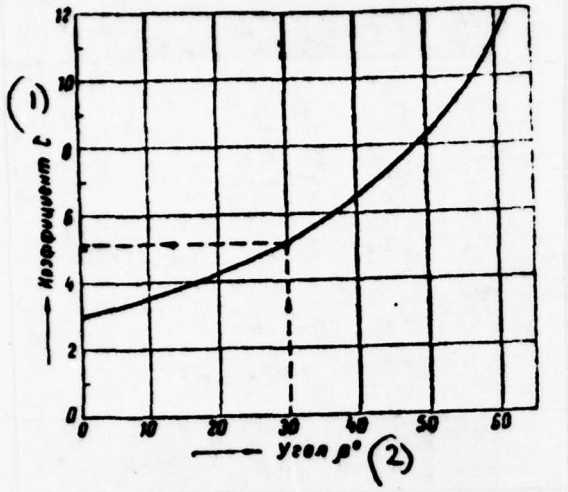


Fig. 10.27. Nomogram for determination without dimension factors of A and B for calculation of equal-arm L-shaped section of pipeline taking into account rotation are more than 90° without taking into account of flexibility of branch/removal.

Key: (1). Coefficient C. (2). Angle β.

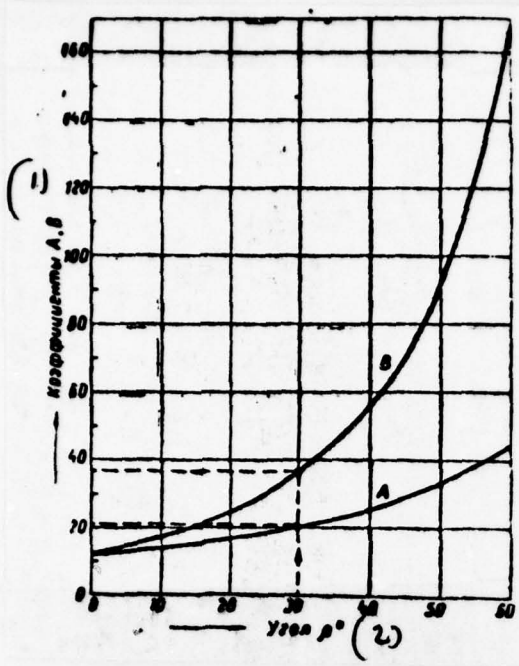


Fig. 10.28. Nomogram for determining dimensionless coefficient of C for calculation of equal-arm L-shaped section of PiPeline with angle of turn is more than 90° without taking into account of flexibility of branch/removal.

Page 202.

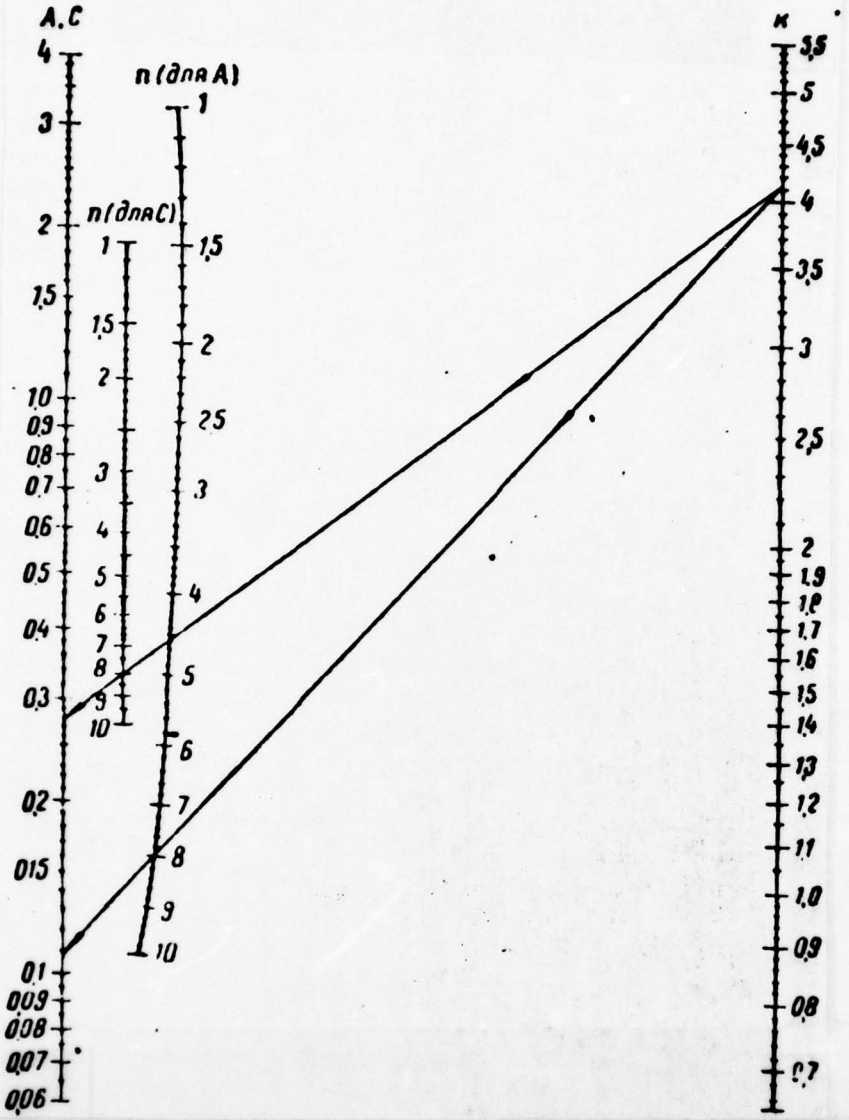


Fig. 10.29. Nomogram for determining dimensionless coefficients of A and C for calculation of equal-arm L-shaped section of pipeline with angle of rotation 90° taking into account flexibility of branch/removal.

Page 203.

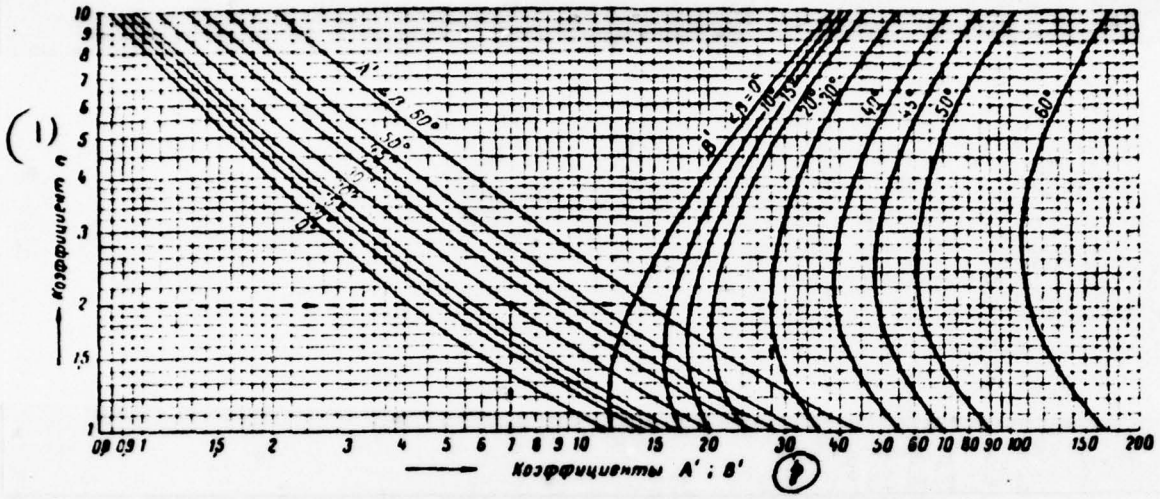


Fig. 10.30. Nomogram for determining dimensionless coefficients A' and B' for calculation of L-shaped section of pipeline with angle of rotation is more than 90° without taking into account of flexibility of branch/removal.

Key: (1). Coefficient. (2). Coefficients A', B'.

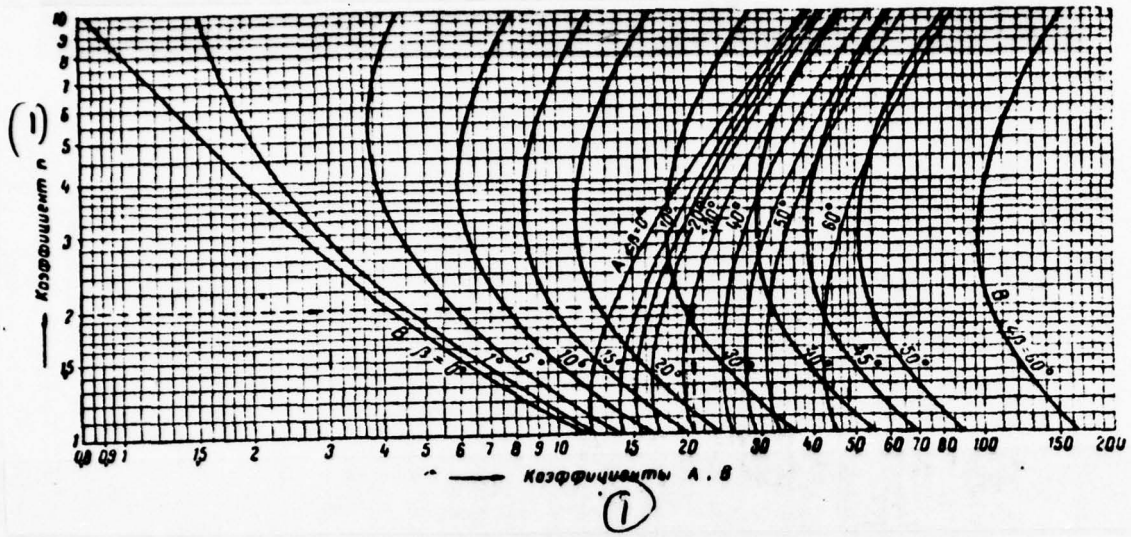


Fig. 10.31. Nomogram for determining dimensionless coefficients of A and B for calculation of L-shaped section of pipeline with angle of rotation are more than 90° without taking into account of flexibility of branch/removal.

Key: (1). Coefficient. (2). coefficients.

Page 204.

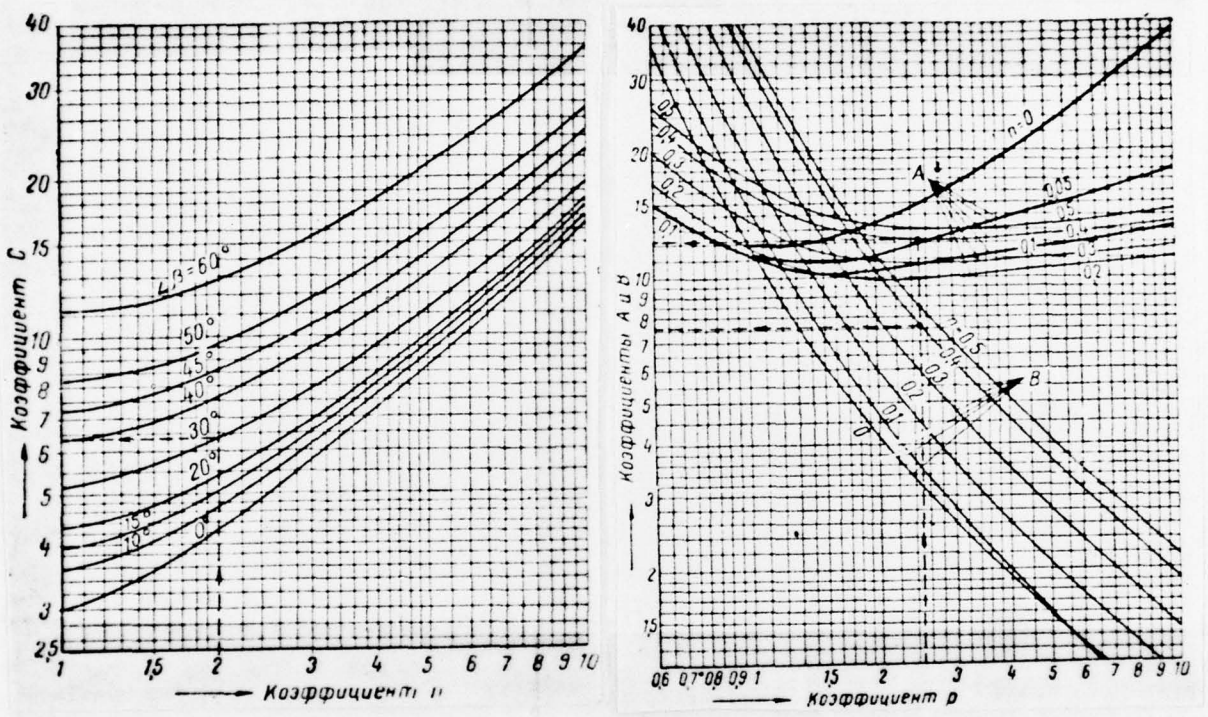


Fig. 10.32. Nomogram for determining dimensionless coefficient of C for calculation of L-shaped section of pipeline with angle of rotation is more than 90° without taking into account of flexibility of branch/removal.

Fig. 10.33. Nomogram for determining dimensionless coefficients of A and B for calculation of z-shaped section.

of pipeline without flexibility of branch/removal.

Key: (1). Coefficients. (2). Coefficient.

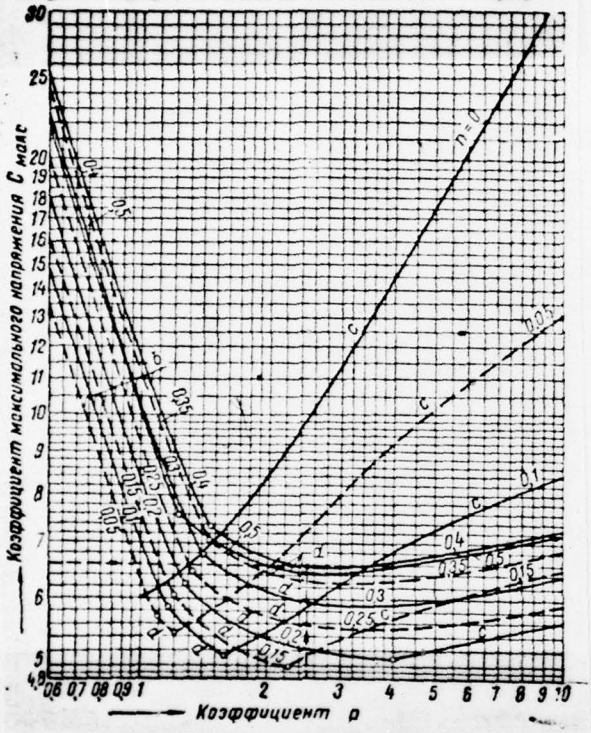


Fig. 10.34 [1]. Nomogram for determining maximum dimensionless coefficient $C_{макс}$ for calculation of z-shaped section of pipeline without taking into account of flexibility of branch/removal. Maximum the stress depending on the value of coefficients of p and n can be at points c, b or d, in connection with which on curve $C_{макс}$ are broken into the sections, designated letter mi c, b and by d, which indicate, at which point there will be maximum stress.

AD-A066 414 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 13/2
DESIGNER'S HANDBOOK - INSTALLING THERMAL PIPELINE SYSTEMS. PART--ETC(U)
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4 of 6
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FOOTNOTE [1]. Nomograms are constructed by Eng. B. V. Rudomino. ENDFOOTNOTE.

Key: (1). Coefficient of maximum stress (2). Coefficient

Page 205.

During the construction of nomograms, the product αE is accepted equal to 2.4 kgf mm/cm² m deg, and the bending compensating stress $-\sigma_{м}^{к}-6 =$ 6 kgf/mm².

When the permissible bending compensating stress, received from stress analysis is less or more than 6 kgf/mm², the length of the smaller compensating arm, obtained from formula (10.152), they recount by the following formula

$$l'_{м} = l_{м}\frac{6}{\sigma^{к}_{м.д}}m. \qquad (10.154)$$

In this case the length of larger arm is determined from the formula

$$l'_{б} = l'_{м}n.m. \qquad (10.155)$$

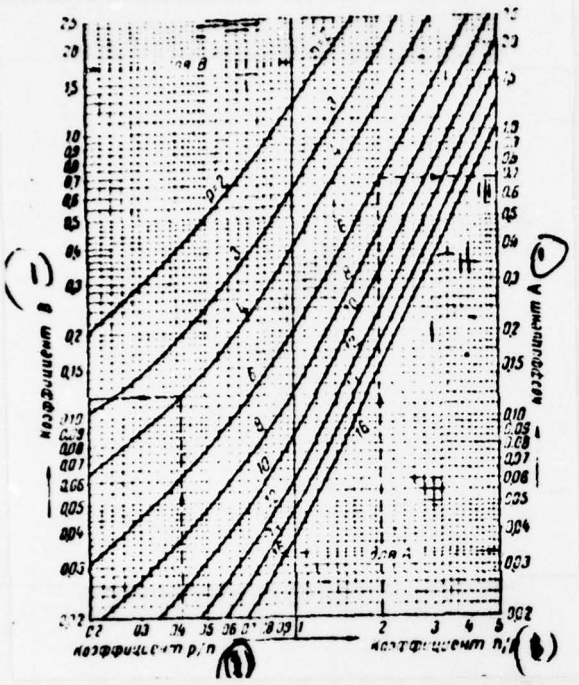


Fig. 10.35. Nomogram for determining dimensionless coefficients of A and B for calculation of L-shaped section of pipeline with angle of rotation 90° taking into account flexibility of branch/removal with k = 2.8.

Key: (1). coefficient.

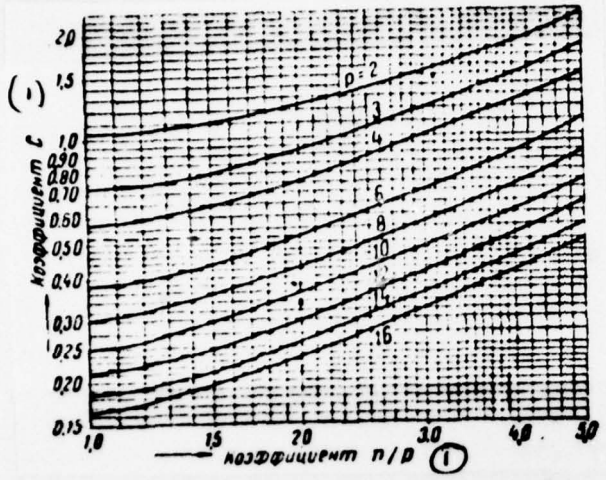


Fig. 10.36. Nomogram for determining dimensionless coefficient of C for calculation of L-shaped section of pipeline with angle of rotation 90° taking into account flexibility of branch/removal with k = 2.8.

Key: (1). coefficient.

Table 10.22. Minimum length of the compensating arms of the L-shaped sections of pipelines with equal arms taking into account the flexibility of branch/removal in m.

Условный проход трубы D_y в мм (1)	Минимальные длины компенсирующих плеч при параметрах теплоносителя: $P_{раб}$ в кгс/см², t в °С (2)				
	$P_{раб}$=16, t=150	$P_{раб}$=8, t=250	$P_{раб}$=13, t=300	$P_{раб}$=16, t=325; $P_{раб}$=21, t=350	$P_{раб}$=[illegible], t=425
25	—	0,9	1,3	1,6	2
32	0,7	1	1,5	1,7	2,5
40	0,8	1,2	1,8	2,1	2,5
50	1	1,4	2,2	2,5	3
70	1,5	2	3	3,5	4
80	1,5	2,1	3,5	4	4,5
100	2	2,6	4	4,7	5,5
125	2	3	5	5,5	6,5
150	2,5	3,5	5,5	6,5	7,5
175	3	4,2	6,5	7,5	9,5
200	3,5	4,9	7,5	8,5	10
250	4	5,8	9	10,5	12
300	5	7	11	12,5	15
350	6	8	12	14,5	17
400	—	—	—	16	19

Notes. 1. The calculated temperature of surrounding air is accepted $t_{н.в}$ = -30°.

2. Longitudinal bending compensating stress is accepted: for water and steam t < 250° C $\sigma_{н(раб)}$ -8 kgf mm²; for pair t > 250°C $\sigma_{н(раб)}$ = 6 kgf/mm².

3. Reach is given taking into account radius of the axis of bent tube R.

Key: (1). The internal diameter of tube Dy in mm. (2).

Minimum lengths of the compensating arms in the parameters of heat carrier: $P_{раб}$ in kg/cm², t in °C.

Page 206.

The minimum lengths of the compensating arms of the L-shaped sections of pipelines with equal arms taking into account the flexibility of the bent smooth branch/removals and without taking into account of the flexibility of branch/removals for tubes on the "assortment of the tubes of thermal grid/networks" are given in table 10.22 and 10.23.

10.5. Calculation for the compensation for the thermal elongations of the sections of pipeline with U-shaped compensators.

The length of the adjacent to U-shaped compensator arms has, as a rule, large extent, in connection with this the reactions of forces of friction of supports bring about the secondary forces of elastic deformation and stress in the

pipelines which are considered taking into account the compensation for thermal elongations by contraction in the lengths of the adjacent free arms in comparison with actual to 40 D_y

If distance from fixed support to compensator less than 40 D_y, in calculation consider the overall length of the compensating section. During setting up, directing supports the reach, considered in calculation, accepts equal to distance from directing support to compensator.

Side-looking all the cases calculated thermal elongation is determined for the actual value of compensating section, i.e., according to the distance between fixed supports.

Table 10.23. Minimum lengths of the compensating arms of the L-shaped sections of pipelines with equal arms without taking into account of the flexibility of branch/removal in m.

(1) Условный проход трубы D_y в мм	Минимальные длины компенсирующих плеч при параметрах теплоносителя: $P_{раб}$ в кгс/см², t в °С (2)														
	$P_{раб}$=16, t=150			$P_{раб}$=8, t=250			$P_{раб}$=13, t=300			$P_{раб}$=16, t=325; $P_{раб}$=21, t=350			$P_{раб}$=36, t=425		
	Угол β в град (3)														
	0	30	60	0	30	60	0	30	60	0	30	60	0	30	60
100	1,7	3	6,5	3,5	6,2	13,5	4,2	7,3	15,7	4,8	8,2	17,8	5,5	9,5	
125	2,2	3,7	8	4,4	7,7	16,5	5,2	9	19,3	5,8	10,2		6,8	11,7	
150	2,6	4,5	9,6	5,3	9,2	20	6,5	10,7	23	7	12,2		8	14	
175	3	5,5	12	6,5	11	24	7,5	13		8,5	15		10	17	
200	3,5	6	13	7,5	13	27,5	8,5	15		9,5	17		11	19,5	—
250	4,5	7,5	16,5	9	16	34	10,5	18,5		12	21	—	14	24	
300	5,5	9	20	11	19		12,5	22		14,5	25		16,5	28,5	
350	6	10,5	22,5	12,5	21,5		14,5	25		16,5	28,5		19	33	
400	7	12	25,5	14	24,5		16,5	28,5		19	32,5		21,5	37	
400	9	16	34	14	24,5		16,5	28,5	—						
450	10	18	39	16	27,5		18,5	32							
500	11,5	20	42,5	17,5	30,5		20,5	35,5							
600	13,5	23,5	51	21	36		24,5	42,5							
700	15,5	26,5		24	41,5		28	48,5							
800	18	31	—	27,5	47,5	—	32								
900	20	34		31	—		35,5								
1000	22	38		34			39,5								

Notes: 1. Heavy lines emphasized the maximum recommended lengths of the compensating arms during auto/self-compensation.

2. Cm. note 1 and 2 to table 10.22.

Key: (1). The internal diameter of tube D_y in mm. (2). Minimum lengths of the compensating arms in the parameters of the heat carrier: $P_{раб}$ in kgf/cm³, t in °C. (3). Angle β in deg.

Page 207.

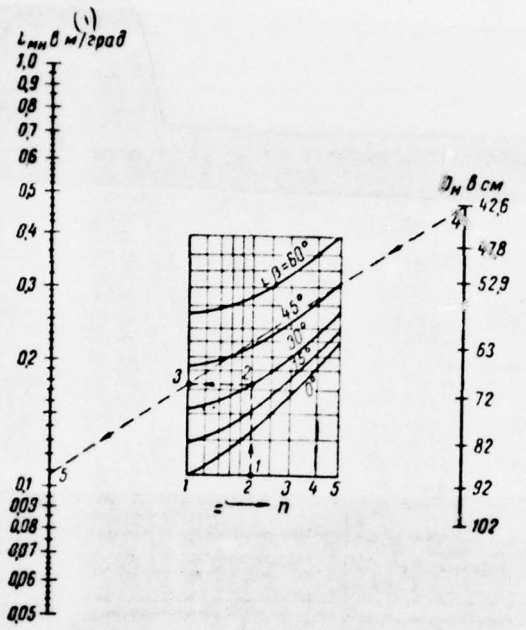


Fig. 10.37. Nomogram for determining length of smaller compensating arm $l_{мн}$, in reference to 1°C calculated differences in temperatures for $D_н$ = 42.6-102 cm.

Key: (1). m/deg.

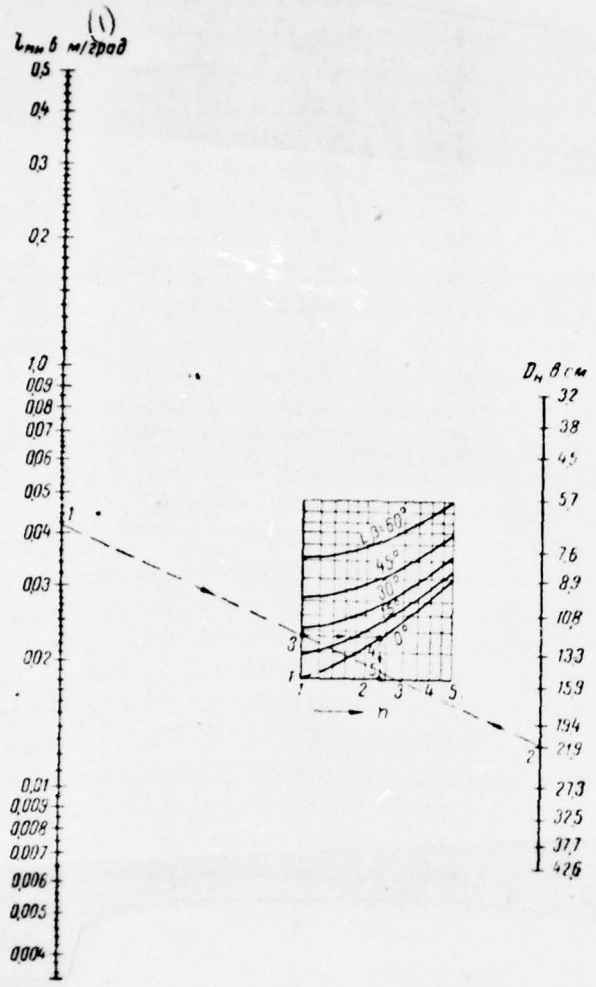


Fig. 10.38. Nomogram for determining the length of the smaller compensating arm $l_{мн}$ in reference to 1°C calculated differences in the temperatures for $D_н$ = 3.2-42.6 cm.

Key: (1). m/deg.

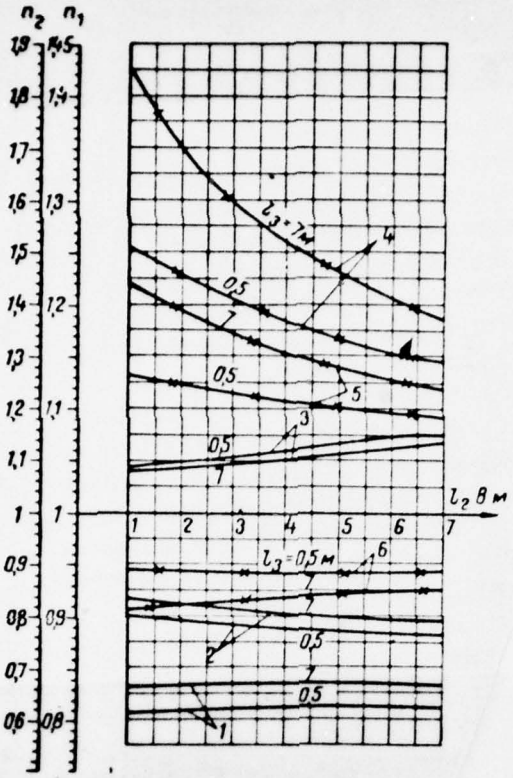


Fig. 10.39. Graph of correction factors, which characterize effect of lengths of adjacent free arms, considered in calculation for $D_н \times s$ = 108 x 4 mm and R = 500 mm. 1 - n_1 - to compensation capacity with $l_п$=0; 2 - the same, when $l_п$=10 D_y; 3 - the same, with $l_п$=80 D_y 4 - n_2 - to the force of elastic deformation when $l_п$=0; 5 - the same, when $l_п$=10 D_y; 6 - the same when $l_п$=80 D_y

The effect of the length of the adjacent free arms, considered in calculation, on compensation capacity and the force of elastic deformation is evident from the graphs, given in Fig. by 10-39-10.41, constructed for U-shaped compensators with the smooth bent branch/removals. During the construction of graphs of the value of the force of elastic deformation and the compensation capacity of compensator, ability of compensator, determined at the length of the adjacent free arms, equal to $l_n=40\,D_y$, are accepted as unity, but for the values of these quantities when $l_n=10\,D_y$, $80\,D_y$, $0D_y$ are given correction factors n_1 - to compensation capacity and n_2 - to the force of elastic deformation of compensator. The data of these and other graphs are generalized and given in the form of the averaged coefficients in table 10.24.

If U-shaped compensator is furnished not along the middle of section, but they misalign to the side of one of the fixed supports, then the forces of elastic deformation and stress increase approximately by 20-40o/o with respect to the forces of elastic deformation and by the stress, received for the compensator, arrange/located in the middle.

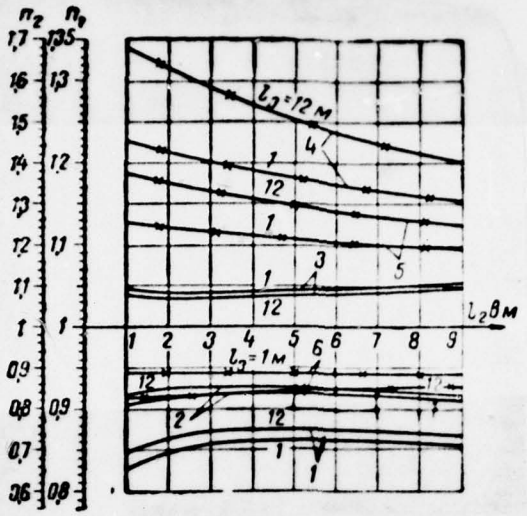


Fig. 10.40. Graph of correction factors, which characterize the effect of the lengths of the adjacent free arms, considered in calculation for $D_н \times s$ = 219 x 6 mm and R = 850 mm. 1 - n_1 - to compensation capacity when $l_п$=0; - 2 - the same, when $l_п$=10 D_y; 3 - the same, when $l_п$=80 D_y; 4 - n_2 - to the force of elastic deformation when $l_п$=0; 5 - the same, when $l_п$=10 D_y; 6 - the same, when $l_п$=80 D_y

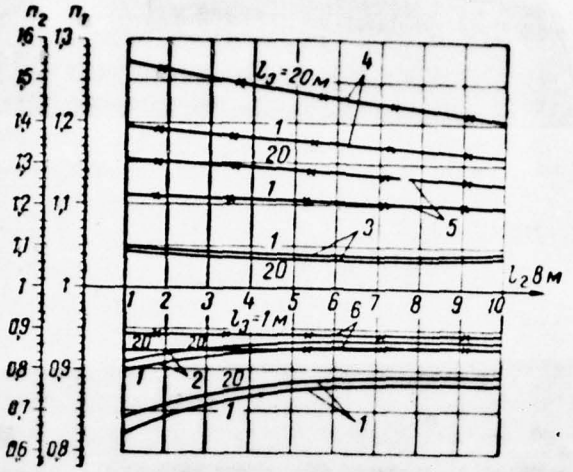


Fig. 10.41. Graph of the correction factors, which characterize the effect of the lengths of the adjacent free arms, considered in calculation for $D_н \times s = 426$ x 9 mm, R = 1700 mm. 1 - n_1 - to compensation capacity when $l_п = 0$: 2 - the same, when $l_п = 10\ D_y$: 3 - the same, when $l_п = 80\ D_y$: 4 - n_2 - to the force of elastic deformation when $l_п = 0$: 5 - the same, when $l_п = 10\ D_y$: 6 - the same, when $l_п = 80\ D_y$

Table 10.24. Values of correction factors of n_1 and n_2.

(1) Длина прилегающих плеч, учитываемых в расчете, $l_п$	(2) Поправочный коэффициент	
	к (3) компенсирующей способности n_1	к (4) силе упругой деформации n_2
40 D_y	1	1
10 D_y	0.9	1.3
0 D_y	0.8	1.7

Key: (1). Length of the adjacent arms, considered in calculation (2). Correction factor. (3). to compensation capacity n_1. (4). to the force of elastic deformation n_2.

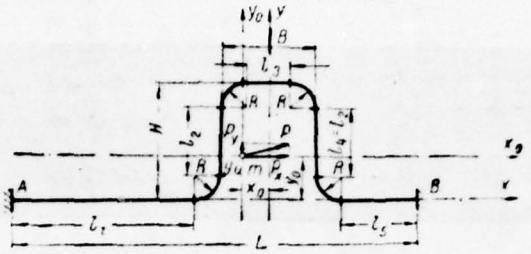


Fig. 10.42. Section of conduit/manifold with unsymmetric U-shaped compensator with the smooth bent branch/removals with $l_1 > l_5$.

Page 209.

Section of conduit/manifold with asymmetric U-shaped compensator with the bent smooth branch/removals.

The diagram of calculated section is given in Fig. 10.42.

Calculation is performed by the formulas:

the reduced length of the centerline of the section

$$L_{np} = l_1 + 2l_2 + l_3 + l_5 + 6{,}28Rk \text{ м}; \quad (10.156)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{(l_1 + l_3 + l_5 + 4R)(l_5 - l_1)}{2L_{np}} \text{ м}; \quad (10.157)$$

$$y_0 = \frac{(l_2 + 2R)(l_2 + l_3 + 3{,}14Rk)}{L_{np}} \text{ м}; \quad (10.158)$$

the central moments of inertia relative to axle/axes x_0 and y_0:

$$I_{x0} = \frac{l_2^3}{6} + (2l_3 + 4l_3)\left(\frac{l_2}{2} + R\right)^2 + \\ + 6{,}28Rk\left(\frac{l_2^2}{2} + 1{,}635l_2R + 1{,}5R^2\right) - \\ - L_{np}y_0^2 \text{ м}^3; \quad (10.159)$$

$$I_{y0} = \frac{l_1^3 + l_3^3 + l_5^3}{12} + \frac{l_1}{4}(l_1 + l_3 + 4R)^2 + \\ + \frac{l_5}{4}(l_3 + l_5 + 4R)^2 + l_3\left(\frac{l_3}{2} + R\right)^2 + \\ + 1{,}57Rk\left(l_3^2 + 4l_3R + 4{,}9R^2\right) - L_{np}x_0^2 \text{ м}^3; \quad (10.160)$$

central product of inertia relative to axle/axes x_0, y_0

$$I_{xy0} = -L_{np}x_0y_0 \text{ м}^3. \quad (10.161)$$

Calculated thermal elongation along X-axis is determined from formula (10.43).

Force of elastic deformation is determined from formulas (10.110) and (10.111).

As the maximum bending moment they accept greatest of

the bending moments:

$$M = P_x(H - y_0) + P_y\left(-x_0 + \frac{l_3}{2}\right) \text{кгсм}; \quad (10.162)$$

$$M = P_x y_0 + P_y\left(l_3 + 2R + \frac{l_3}{2} + x_0\right) \text{кгсм}. \quad (10.163)$$

Key: (1). Kg cm.

The bending compensating stresses are determined from formulas (10.50) and (10.51).

When the lengths of the adjacent free arms, considered in calculation on both sides of compensator, are equal to each other (Fig. 10.43), formulas are simplified and take the form:

the reduced length of the centerline of the section of the conduit/manifold:

при $l_п > 0$

$$L_{пр} = 2l_п + 2l_2 + l_3 + 6{,}28Rk \text{ м}; \quad (10.164)$$

при $l_п = 0$

$$L_{пр} = 2l_2 + l_3 + 6{,}28Rk \text{ м}; \quad (10.165)$$

Key: (1). with.

coordinates of the elastic center of gravity:

$$y_0 = \frac{(l_3 + 2R)(l_3 + l_3 + 3{,}14Rk)}{L_{пр}} \text{ м}; \quad (10.166)$$

$$x_0 = 0;$$

the central moment of inertia relative to axle/axis x_0:

$$I_{x_0} = \frac{l_2^3}{6} + (2l_3 + 4l_2)\left(\frac{l_3}{2} + R\right)^2 + 6{,}28Rk\left(\frac{l_2^2}{2} + 1{,}635l_3R + 1{,}5R^2\right) - L_{пр}y_0^2 \text{ м}^3. \quad (10.167)$$

Calculated thermal elongation along X-axis is determined from formula (10.43).

Forces of elastic deformation:

$$P_x = P_к = \frac{\Delta x EI}{l_{x0}(0)^2} \text{ кгс}^{(1)}. \qquad (10.168)$$

$$P_y = 0.$$

Key: (1). kgs

maximum bending moment: with $y_0 \leqslant 0.5H$ at point C

$$M_{макс} = (H - y_0) P_к \text{ кгсм};^{(1)} \qquad (10.169)$$

Key: (1). kgcm

with $y_0 \geqslant 0.5H$ at point D

$$M_{макс} = -y_0 P_к \text{ кгсм}^{(1)} \qquad (10.170)$$

Key: (1). kgcm.

The bending compensating stress is determined from the formulas:

on the back of compensator on the branch/removal

$$\sigma_и^к = \frac{P_к (H - y_0) m}{W} \text{ кгс/мм}^2;^{(1)} \qquad (10.171)$$

Key: (1). kgf/mm².

on the sections, adjacent to compensator, on the branch/removal

$$\sigma^{к}_{и(пр)} = \frac{\sigma^{к}_{и} y_0}{(H - y_0)} \text{ (1) кгс/мм²;} \qquad (10.172)$$

Key: (1). kgf/mm²

on the direct/straight sections, which apply to compensator,

$$\sigma^{к}_{и(пр)} = \frac{\sigma^{к}_{и} y_0}{(H - y_0)\, m} \text{ (1) кгс/мм².} \qquad (10.173)$$

Key: (1). kgf/mm².

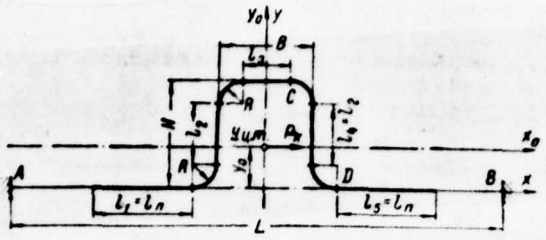


Fig. 10.43. Section of the pipeline with symmetrical U-shaped compensator with bent smooth branch pipes when $l_1=l_3=l_n$

Page 210.

Section of conduit/manifold with unsymmetric U-shaped compensator with welded branch/removals.

The diagram of calculated section is given in Fig.

10.44.

Calculation is performed by the formulas:

the reduced length of the centerline of section, with H = l_2 and B = l_3

$$L_{np} = l_1 + 2l_2 + l_3 + l_5 \text{ м}; \qquad (10.174)$$

of the coordinate of the elastic center of gravity:

$$x_0 = \frac{(l_1 + l_3 + l_5)(l_5 - l_1)}{2L_{np}} \text{ м}; \qquad (10.175)$$

$$y_0 = \frac{l_2(l_2 + l_3)}{L_{np}} \text{ м}; \qquad (10.176)$$

the central moments of inertia relative to axle/axes x_0, y_0:

$$I_{x0} = \frac{l_2^3}{6} + (2l_2 + 4l_3)\frac{l_2^2}{4} - L_{np}\, y_0^2 \text{ м}^3; \qquad (10.177)$$

$$I_{y0} = \frac{l_1^3 + l_3^3 + l_5^3}{12} + \frac{l_1}{4}(l_1 + l_3)^2 + \frac{l_5}{4}(l_3 + l_5)^3 + l_2\frac{l_3^2}{4} - L_{np}\, x_0^2 \text{ м}^3; \qquad (10.178)$$

central product of inertia relative to axle/axes x_0, y_0

$$I_{xy0} = -L_{np} x_0 y_0 \text{ м}^3. \qquad (10.179)$$

Calculated thermal elongation along X-axis is determined from formula (10.43).

The forces of elastic deformation are determined from formulas (10.110) and (10.111).

As the maximum bending moment they accept larger of the torque/moments:

$$M = P_x (H - y_0) + P_y \left(-x_0 + \frac{l_3}{2} \right) \text{кгсм}; \quad (10.180)$$

$$M = P_x y_0 + P_y \left(l_5 + \frac{l_3}{2} + x_0 \right) \text{кгсм}. \quad (10.181)$$

Key: (1). kgcm.

The bending compensating stress is determined from formula (10.50).

With the equality in calculation of the adjacent free arms considered on both sides of compensator (Fig. 10.45) the calculation is performed by the simplified formulas:

the reduced length of the centerline of the section of the conduit/manifold

$$L_{пр} = 2l_п + 2H + B \text{ м}; \quad (10.182)$$

the coordinate of the elastic center of gravity

$$y_0 = \frac{H(H+B)}{L_{пр}} \text{ м}; \quad (10.183)$$

$$x_0 = 0;$$

the central moment of inertia relative to axle/axis x_0

$$I_{x0} = \left(\frac{2}{3} H + B \right) H^2 - L_{пр} y_0^2 \text{ м}^3. \quad (10.184)$$

Calculated thermal elongation along X-axis are determined from formula (10.43), and the forces of elastic deformation - according to formula (10.168).

The maximum bending moment with $y_0 \leqslant 0.5H$ and $y_0 \geqslant 0.5H$ is determined from formulas (10.169) and (10.170).

Bending compensating stress: on the back of the compensator

$$\sigma_{и}^{к} = \frac{(H - y_0) P_к}{W} \text{ (1) } кгс/мм^2; \qquad (10.185)$$

Key: (1). kgf/mm².

on the direct/straight sections, adjacent to compensator,

$$\sigma_{и(пр)}^{к} = \frac{y_0 P_к}{W} = \sigma_{и}^{к} \frac{H + B}{2l_п + H} \text{ (1) } кгс/мм^2. \qquad (10.186)$$

Key: (1). kgf/mm².

U-shaped compensators with sharply bent branch/removals can be designed from formulas for compensators with welded branch/removals.

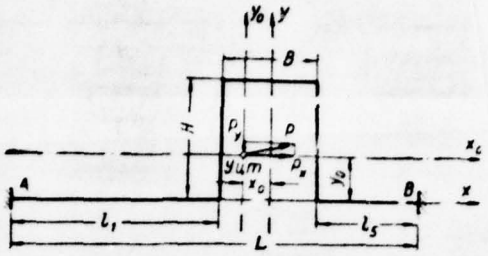


Fig. 10.44. Section of conduit/manifold with unsymmetric U-shaped compensator with welded branch/removals with $l_1 > l_5$.

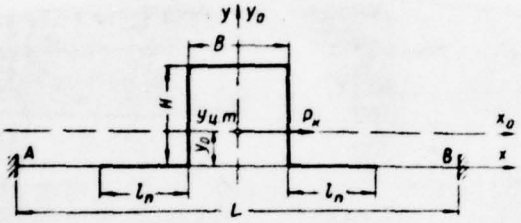


Fig. 10.45. Section of conduit/manifold with symmetrical U-shaped compensator with welded branch/removals with $l_1 = l_5 = l_п$.

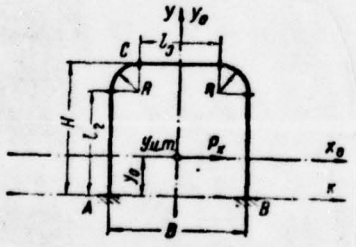


Fig. 10.46. U-shaped section of conduit/manifold with the

bent smooth branch/removals without the adjacent arms.

Page 211.

U-shaped section of conduit/manifold with the bent smooth branch/removals without the adjacent arms.

The diagram of calculated section is given in Fig. 10.46.

Calculation is performed by the formulas:

the reduced length of the centerline of the section of the conduit/manifold

$$L_{np} = 2l_1 + l_3 + 3,14Rk \quad м; \qquad (10.187)$$

of the coordinate of the elastic center of gravity:

$$y_0 = \frac{l_2^2 + l_3(l_2 + R) + 3,14Rk(l_2 + 0,64R)}{L_{np}} \quad м;$$

$$x_0 = 0; \qquad (10.188)$$

the central moment of inertia relative to axle/axis x_0

$$I_{x0} = 0,67l_2^3 + 0,298kR^3 + l_3(l_2^2 + 2l_2R + R)^2 +$$
$$+3,14kR(l_2 + 0,64R)^2 - y_0^2 L_{np} \quad м^3; \qquad (10.189)$$

calculated **thermal elongation** along X-axis

$$\Delta x = \alpha \Delta t B \text{ мм}. \qquad (10.190)$$

The **forces of elastic** deformation the **maximum** bending moment are determined from formulas (10.168)-(10.170).

The bending compensating stresses are determined on the back of compensator on branch/removal according to formula (10.171), and at points A and B - according to formula (10.172).

U-shaped section of conduit/manifold with welded branch/removals without the adjacent arms.

The diagram of calculated section is given in Fig. 10.47.

Calculation is performed by the formulas:

coordinates **of elastic center** of gravity

$$y_0 = \frac{H(H+B)}{2H+B} \text{ м}; \qquad (10.191)$$
$$x_0 = 0.$$

forces of elastic strain

$$P_x = \frac{\alpha \Delta t B E I}{H^3 \left[\frac{2}{3} H + B - \frac{(H+B)^2}{2H+B}\right] 10^7} \overset{(1)}{\text{кгс}}; \qquad (10.192)$$
$$P_y = 0.$$

Key: (1). kgf.

the maximum bending moment with $y_0 \leqslant 0.5H$ and $y_0 \geqslant 0.5H$ is determined from formulas (10.169) and (10.170), bending compensating stresses is determined on the back of compensator according to formula (10.185), and at points A and B - according to formula (10.186).

For the facilitation of labor-consuming calculations for the compensation for the thermal elongations of the sections of conduit/manifolds with U-shaped compensators, are constructed the nomograms in which the flight of compensator and the force of elastic deformation are determined depending on the value of calculated thermal elongation Δx and of the size/dimension of the back of compensator B. Nomograms for the calculation of compensators with the bent smooth branch/removals (see Fig. 10.43) are given in Fig. 10.48-10.68 and with welded branch/removals (see Fig. 10.45) are given in Fig. to 10.69-10.81. The latter it is possible to use, also, for the calculation of compensators with sharply bent branch/removals.

Nomograms are constructed without taking into account preliminary bracing of compensators (when value $\varepsilon = 1$) and under the condition of the equality of the adjacent free arms, considered in calculation on both sides of compensator.

During the compilation of nomograms, it is accepted:

a) the permissible bending compensating stress on the back of compensator in cold state $\sigma^{1}_{н.к\,(хол)} = 11$ kgf/mm²;

b) the modulus of elasticity of tube steel at the temperature of the wall of tube 20°C $E = 2.05 \cdot 10^{6}$ in kg/cm²;

c) the length of the adjacent free arms, considered in calculation from each side of compensator, $l_{п} = 40\,D_{у}$ in m;

d) for nomograms with welded branch/removals the slenderness ratio of branch/removals and the stress concentration factor, equal to unity ($k = 1$, $m = 1$), but a radius of the axle/axis of branch/removal by the

conditionally equal to zero (R = 0);

e) for nomograms with the bent smooth branch/removals the slenderness ratio of branch/removals k the stress concentration factor m of table 10.13, but a radius of the axle/axis of branch/removal - indicated on nomograms;

f) the wall thicknesses of tubes s the moments of resistance of the cross section of the walls of tubes W, indicated on nomograms.

In connection with the fact that of nomogram are constructed without taking into account of the preliminary bracing of compensators, for the use of nomograms, is determined the calculated thermal elongation of the designed section of the conduit/manifold:

with the value of the preliminary bracing, equal to 50o/o of total thermal elongation of section (Δl):

(1) при $t < 250°$ C
$$\Delta x_н = 0{,}5\Delta l \text{ мм}; \quad (10.193)$$
(1) при t от 250 до 300° C
$$\Delta x_н = 0{,}6\Delta l \text{ мм}; \quad (10.194)$$
(1) при t от 300 до 400° C
$$\Delta x_н = 0{,}7\Delta l \text{ мм}. \quad (10.195)$$

Key: (1). with.

where Δl is complete thermal elongation of the calculated section of conduit/manifold in mm [see formula (10.39)];

with the value of the preliminary bracing, equal to 100o/o of complete thermal elongation (Δl) with $t \geqslant 400^{\circ}C$

If the permissible bending compensating stress on the back of compensator $\sigma^{1}_{и.к\,(хол)}$ is less or more than 11 kgf/mm², the dimensions of compensator are determined according to nomograms during the calculated thermal elongation, determined according to the formula

$$\Delta x'_{н} = \Delta x_{н} \frac{11}{\sigma^{1'}_{и.к}} \text{ мм}, \qquad (10.197)$$

where $\Delta x_{н}$ is the calculated thermal elongation, obtained from formulas (10.193) is (10.196) in mm, and the force of elastic deformation, obtained from nomograms, recount by the formula

$$P'_{к} = P_{к} \frac{\sigma^{1'}_{и.к}}{11} \text{ (1) тс}, \qquad (10.198)$$

Key: (1). ton-force.

where $P_{к}$ - force of elastic deformation, obtained the nomograms, in ton-force.

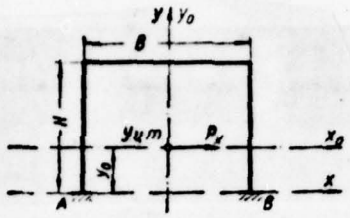


Fig. 10.47. U-shaped section of conduit/manifold with welded branch/removals without adjacent arms.

Page 212.

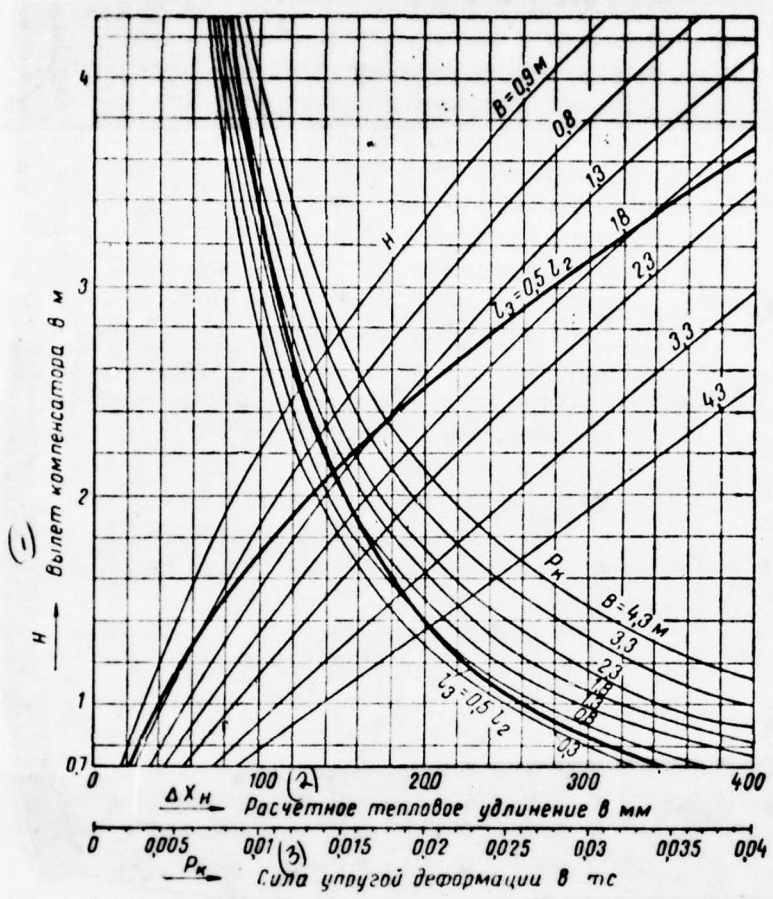


Fig. 10.48. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals.

$D_н$ — 32 мм; s — 3,5 мм; R — 150 мм; W — 1,50 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

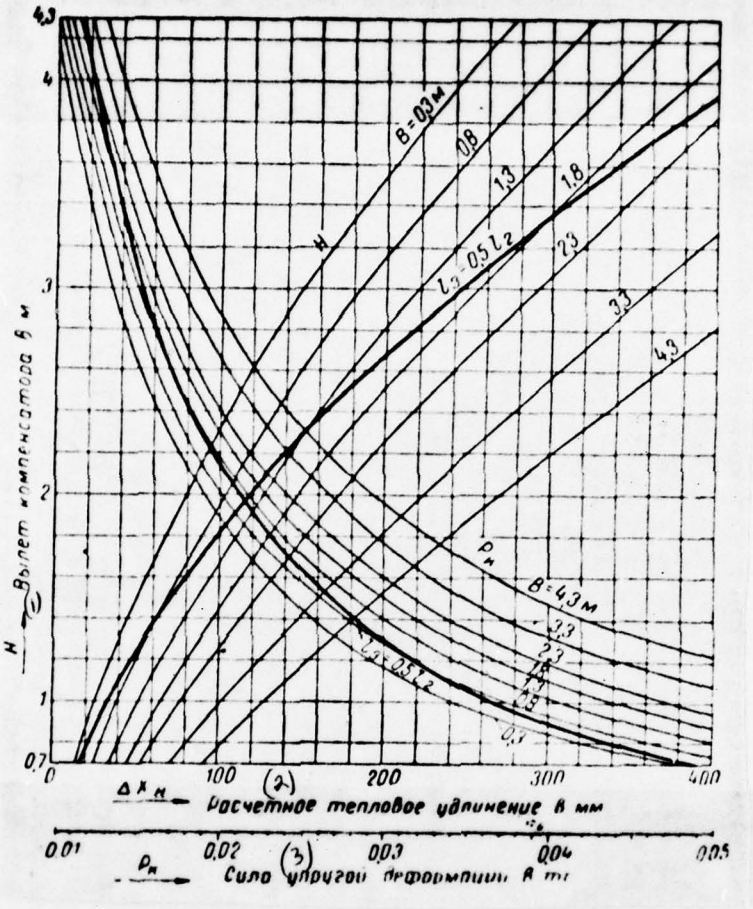


Fig. 10.49. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals.

$D_н$ = 38 мм; s = 2,5 мм; R = 150 мм; W = 2,32 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 213.

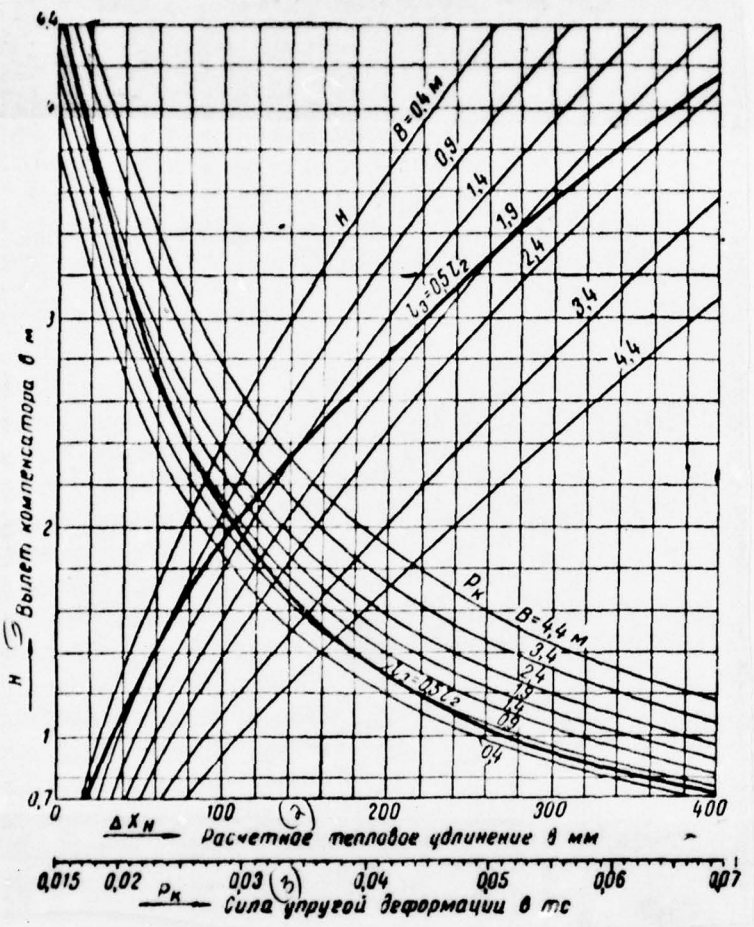


Fig. 10.50. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 45$ мм; $s = 2,5$ мм; $R = 200$ мм; $W = 3,35$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

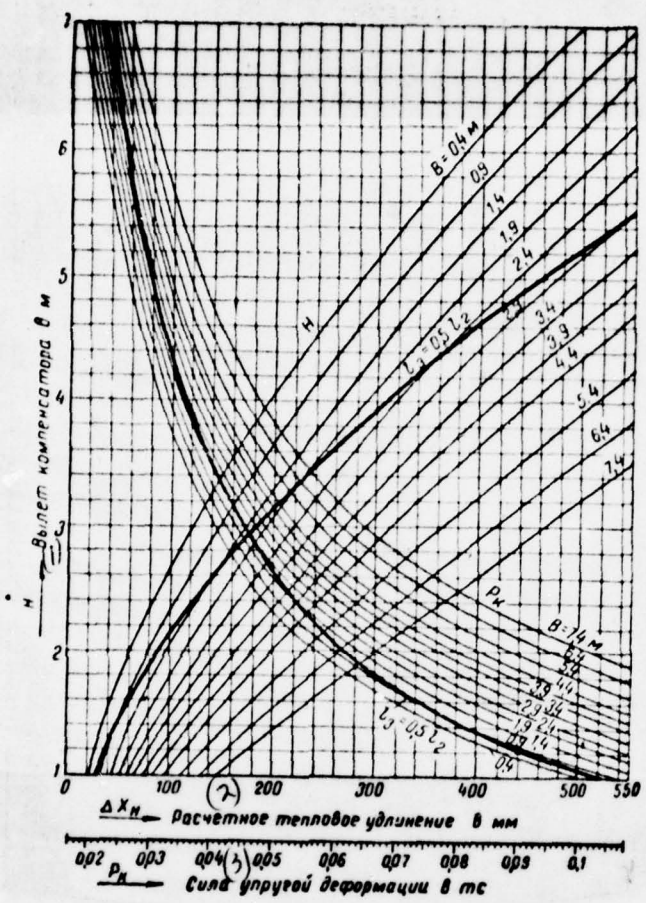


Fig. 10.51. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 57 мм; s = 3,5 мм; R = 200 мм; W = 7,42 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 214.

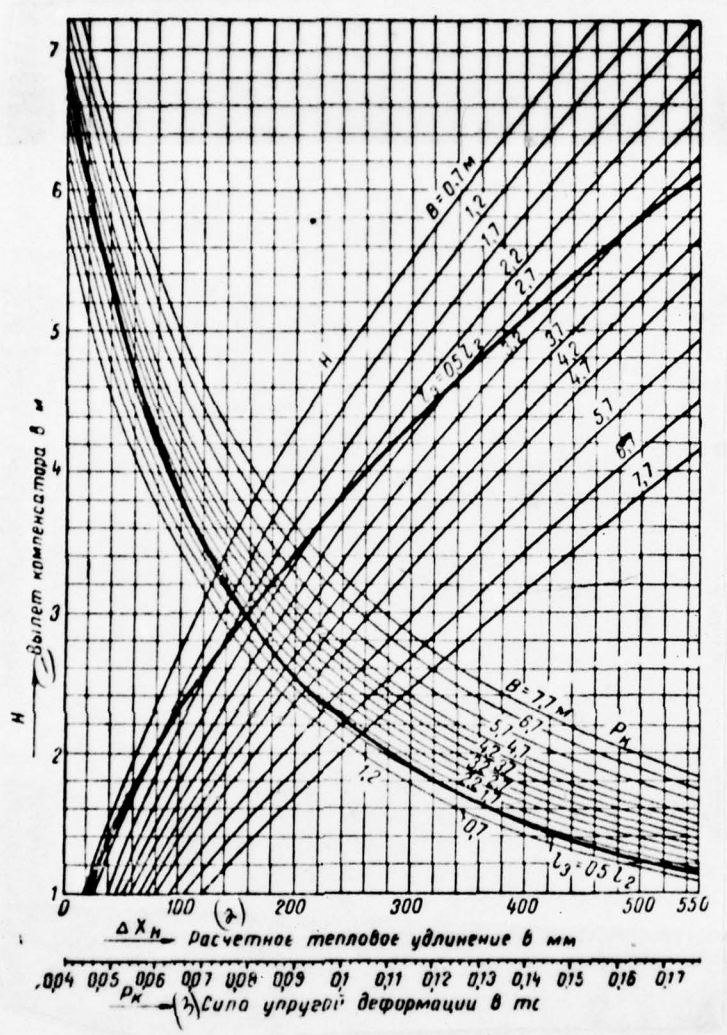


Fig. 10.52. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 76$ мм, $s = 3,5$ мм, $R = 350$ мм, $W = 13,8$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

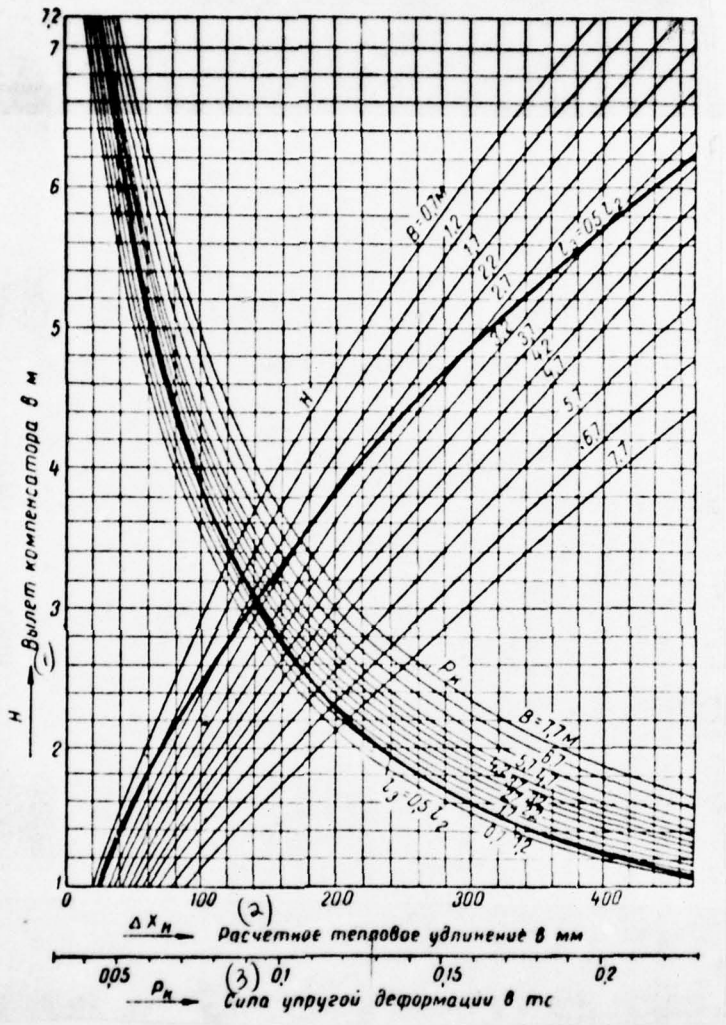


Fig. 10.53. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н^{\text{н}} = 89$ мм; $s = 3{,}5$ мм; $R = 350$ мм; $W = 19{,}3$ см^3

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 215.

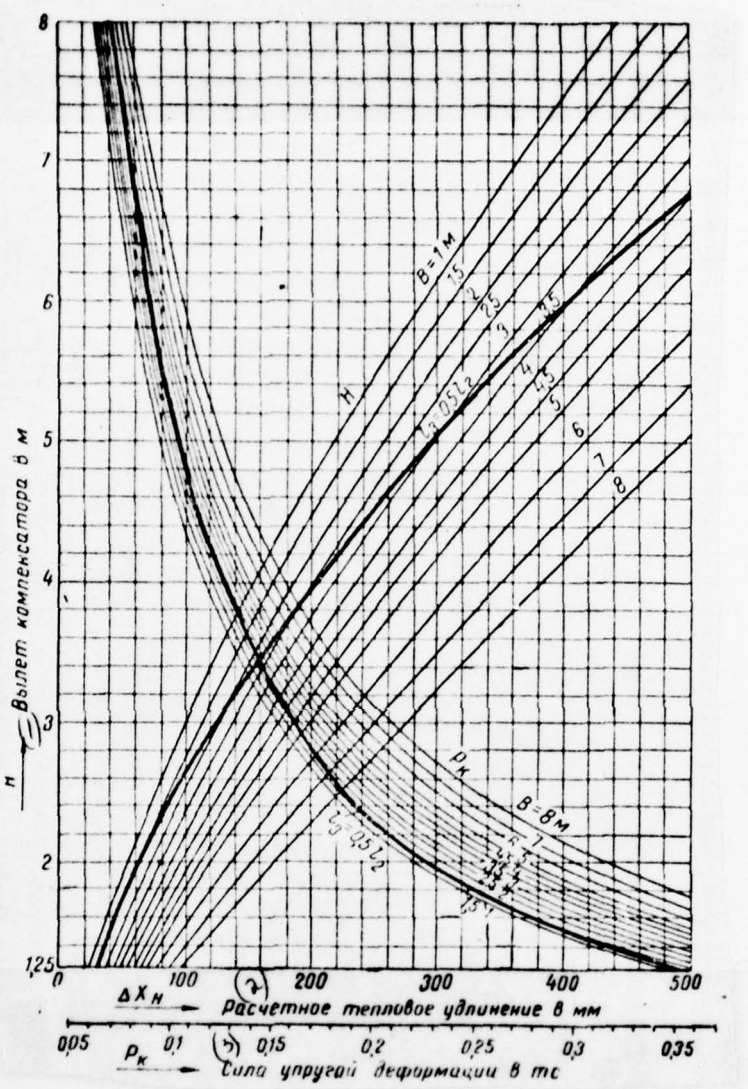


Fig. 10.54. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 108$ мм; $s = 4$ мм; $R = 500$ мм; $W = 32{,}8$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

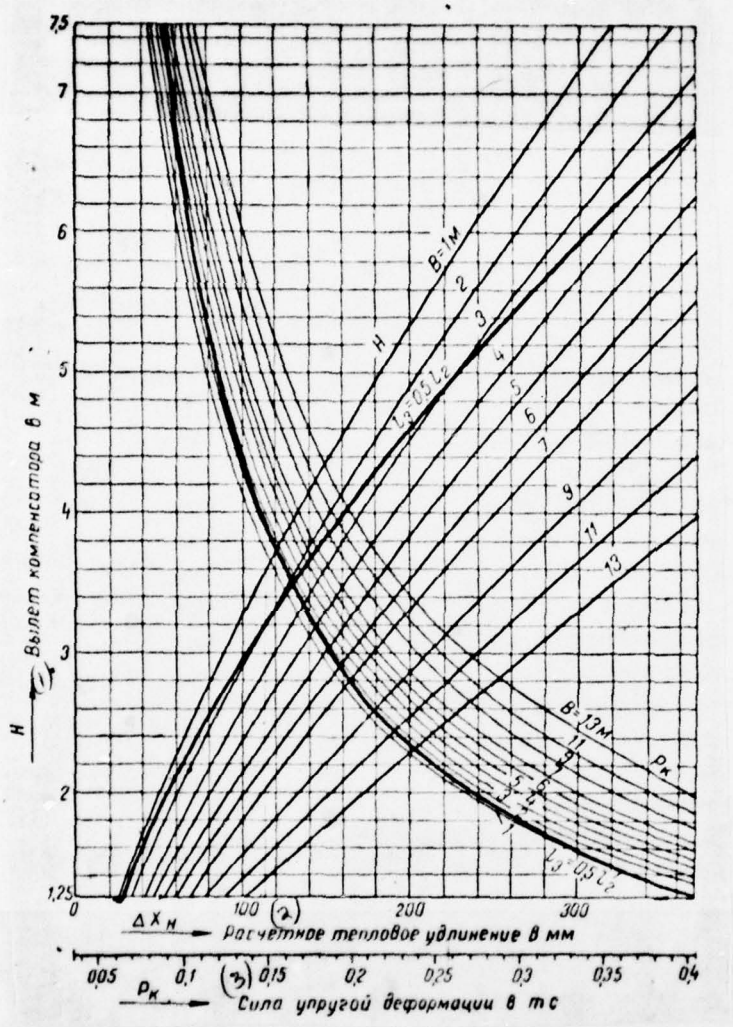


Fig. 10.55. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 133 мм; s = 4 мм; R = 500 мм; W = 50,8 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 216.

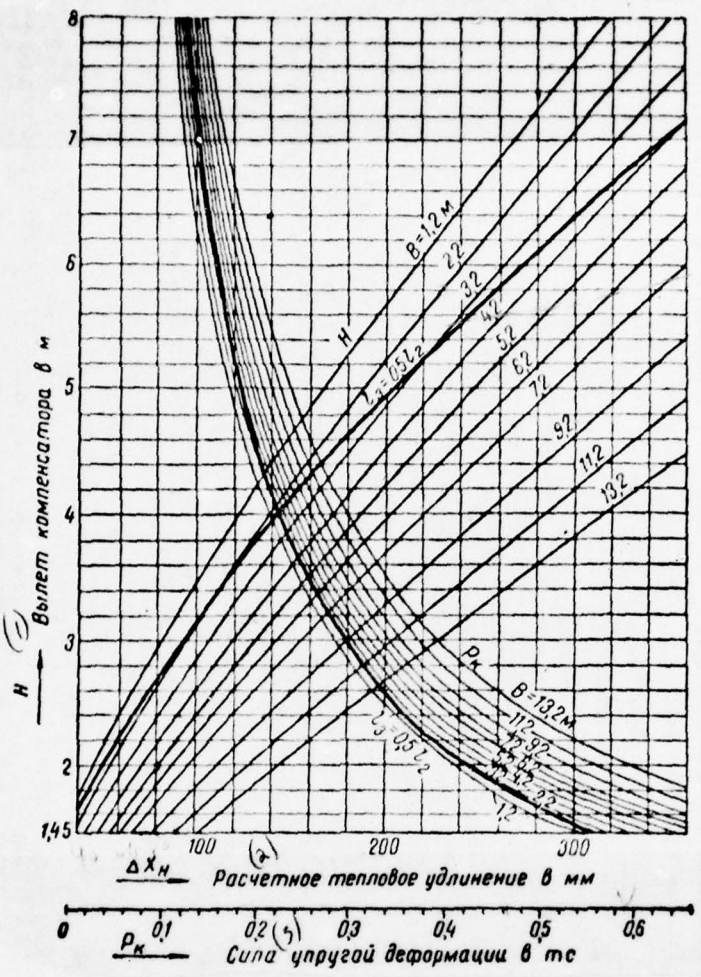


Fig. 10.56. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 159 мм; s = 4,5 мм; R = 600 мм; W = 82 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

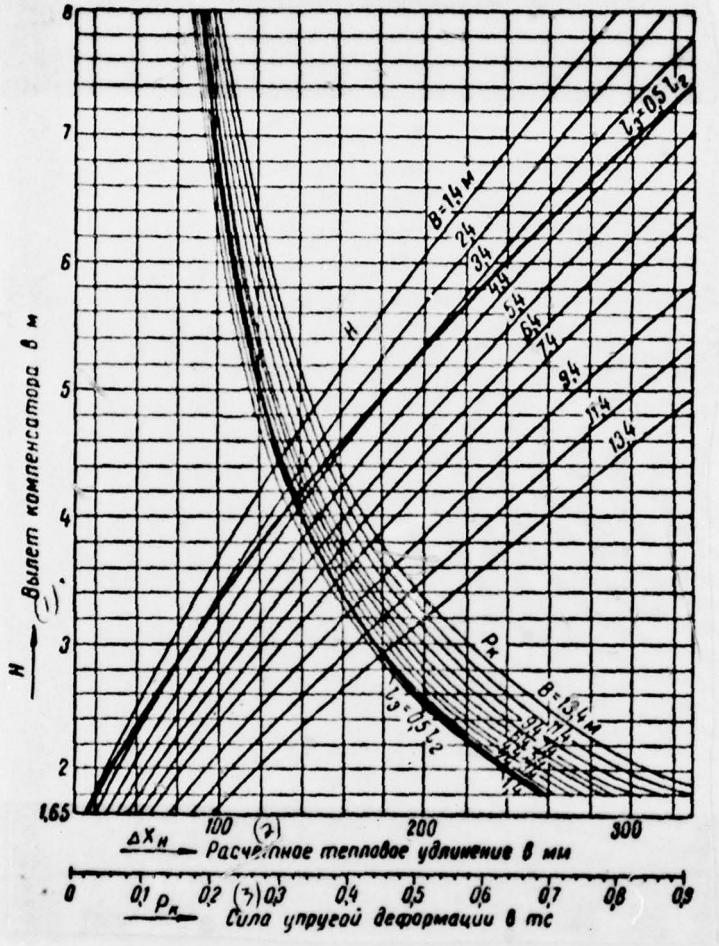


Fig. 10.57. Nomogram for the calculation of U-shapes compensator with the bent smooth branch/removals

$D_н = 194$ мм; $s = 5$ мм; $R = 700$ мм; $W = 137$ см^3

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 217.

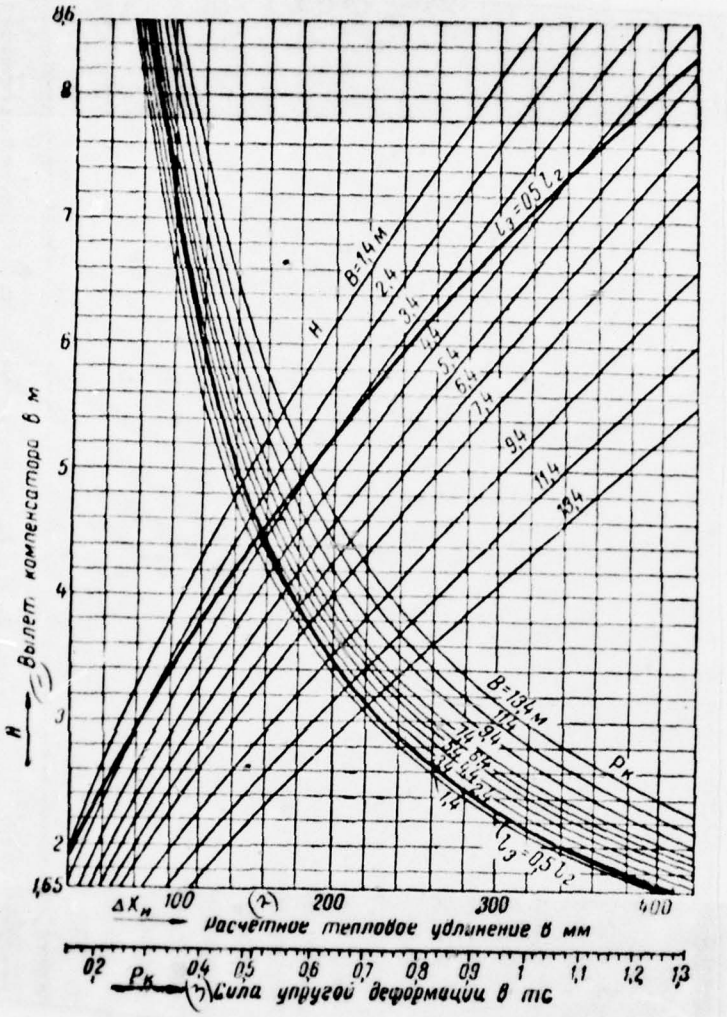


Fig. 10.58. Nomogram for the calculation of-shaped compensator with the bent smooth branch/removals

D_1 = 194 мм; s = 7 мм; $R_г$ = 700 мм; W = 186 т·м²

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

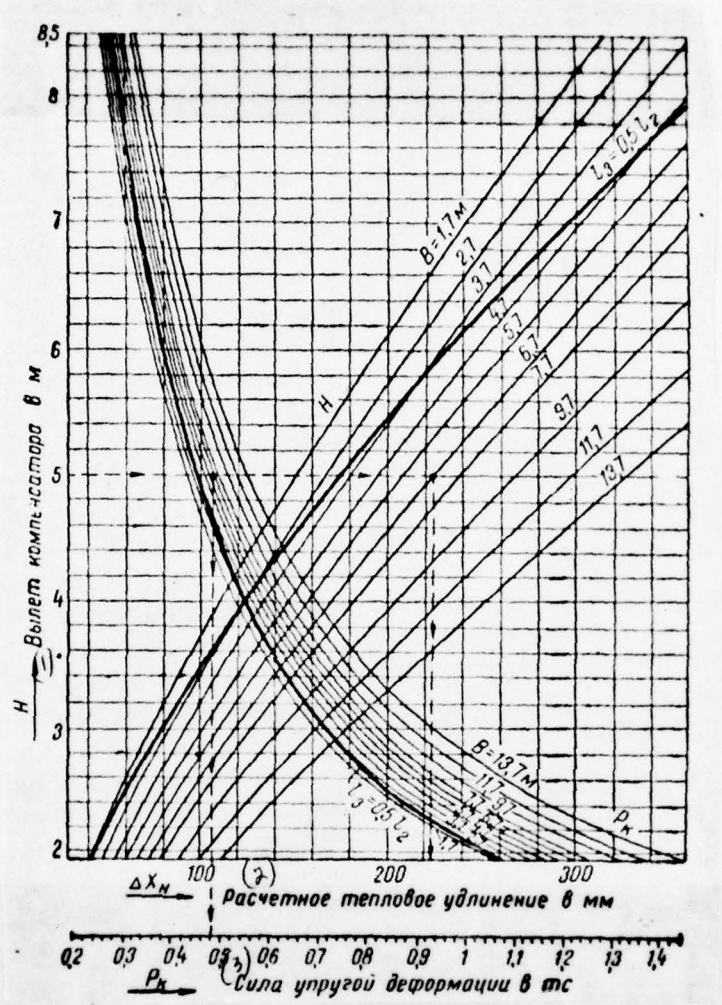


Fig. 10.59. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 219$ мм; $s = 6$ мм; $R = 850$ мм; $W = 208$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 218.

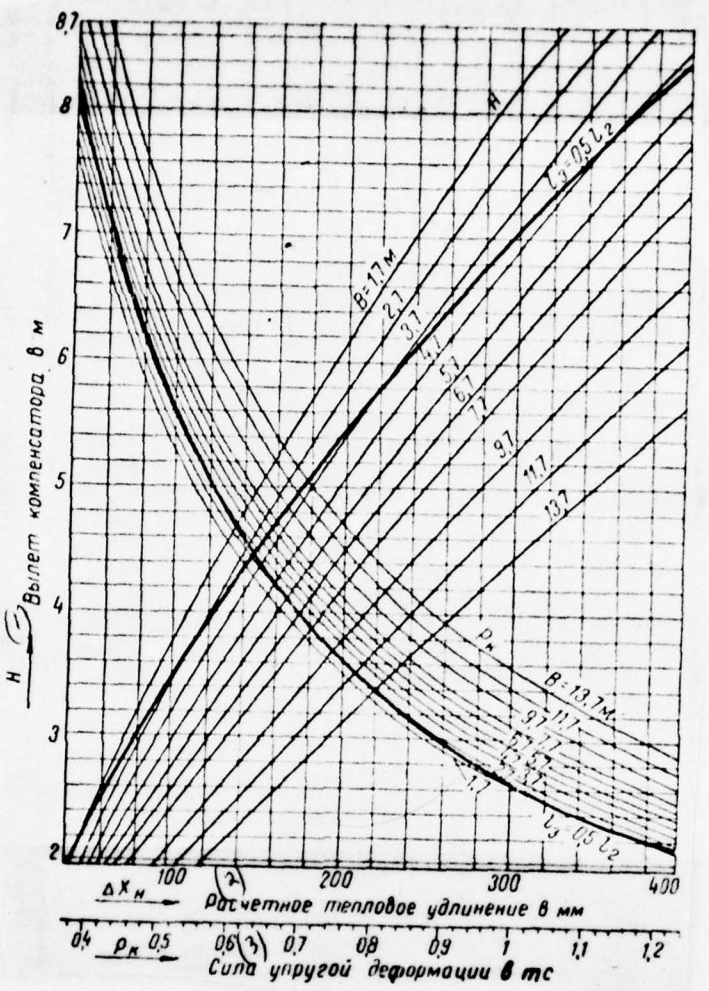


Fig. 10.60. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 219 мм; s = 7 мм; R = 850 мм; W = 239 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

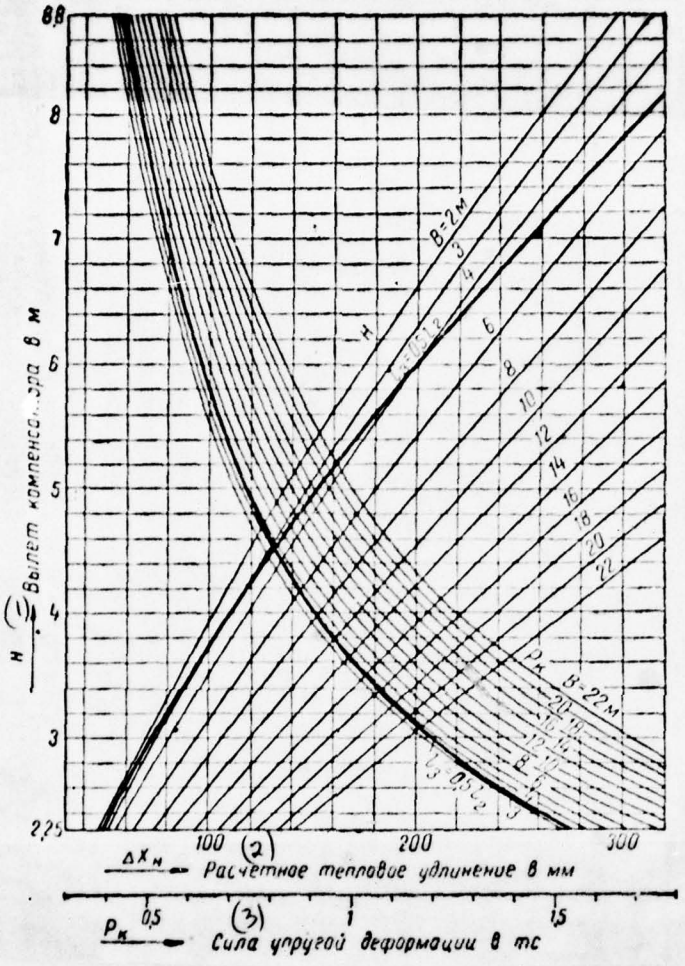


Fig. 10.61. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 273$ мм; $s = 7$ мм; $R = 1000$ мм; $W = 379$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 219.

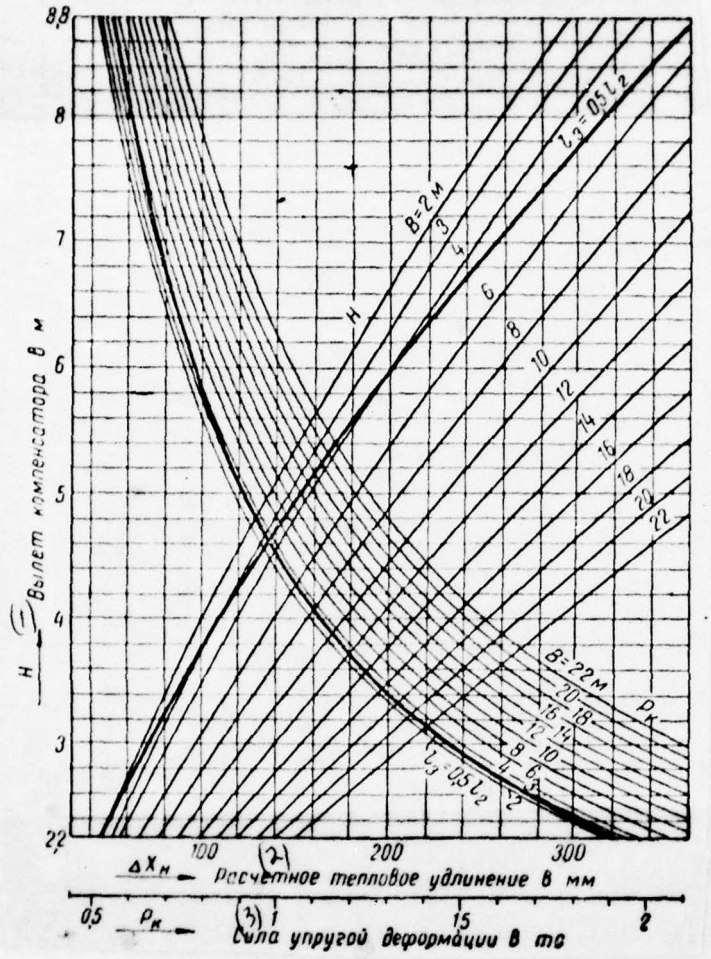


Fig. 10.62. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 273$ мм; $s = 8$ мм; $R = 1000$ мм; $W = 429$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

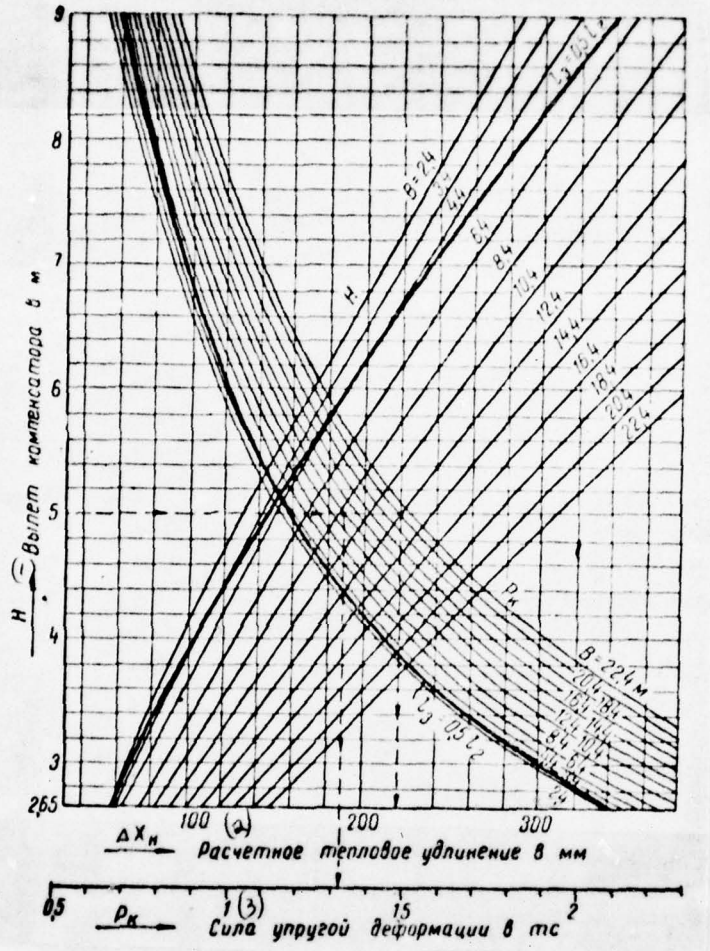


Fig. 10.63. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 325$ мм; $s = 8$ мм; $R = 1200$ мм; $W = 616$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 220.

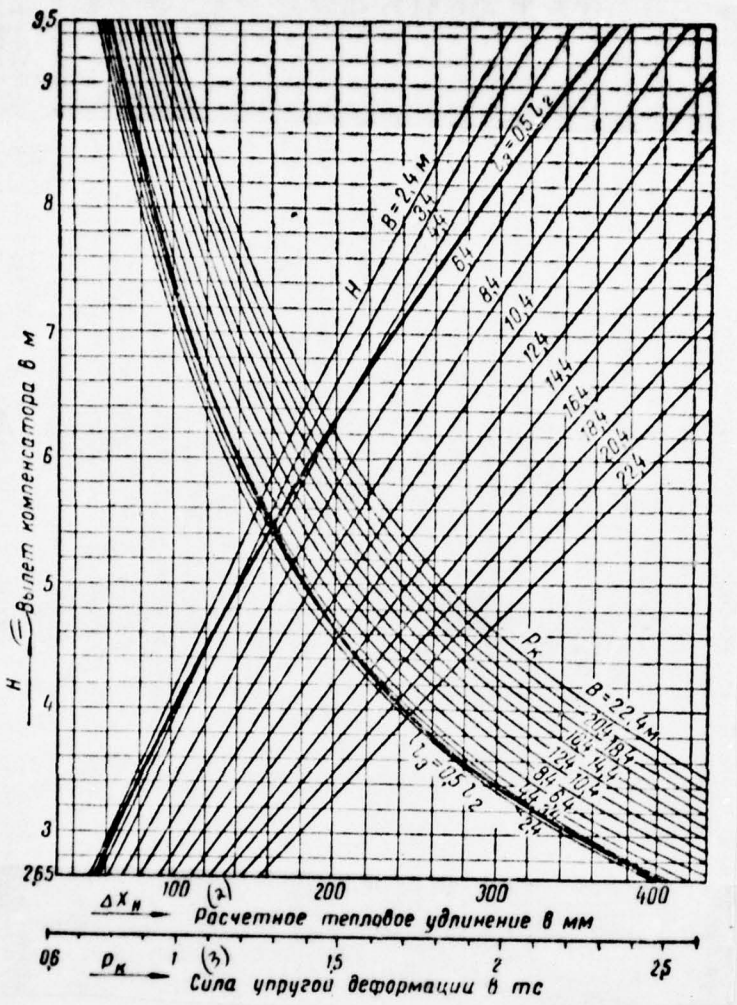


Fig. 10.64. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 325$ мм; $s = 9$ мм; $R = 1200$ мм; $W = 687$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

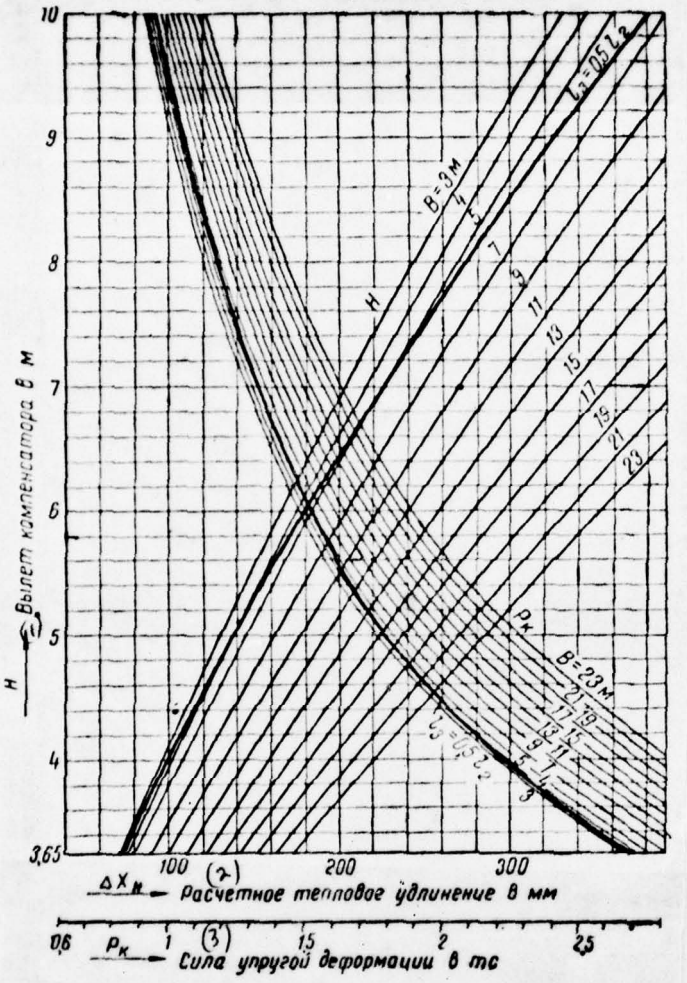


Fig. 10.65. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 377$ мм, $s = 9$ мм, $R = 1500$ мм, $W = 935$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 221.

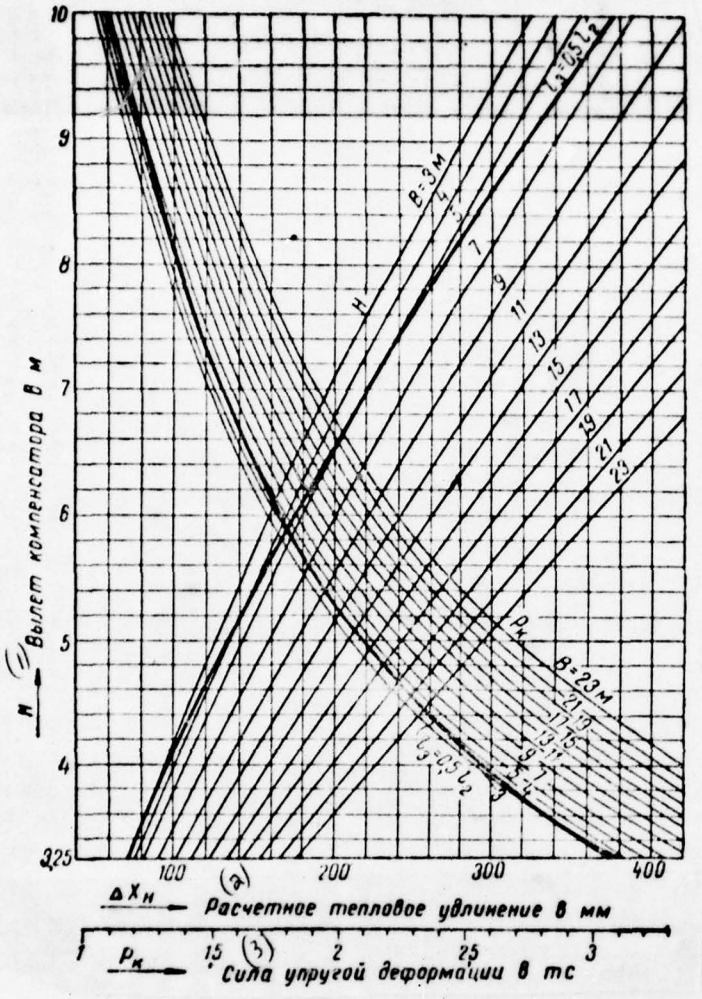


Fig. 10.66. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 377 мм; s = 10 мм; R = 1500 мм; W = 1031 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

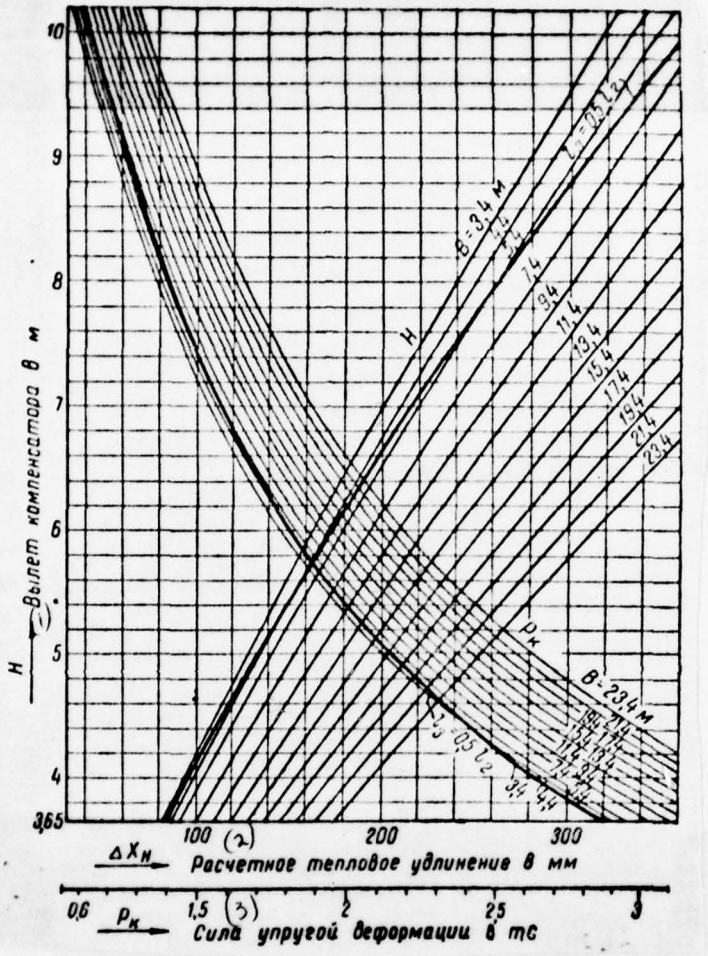


Fig. 10.67. Nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н = 426$ мм; $s = 9$ мм; $R = 1700$ мм; $W = 1204$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 222.

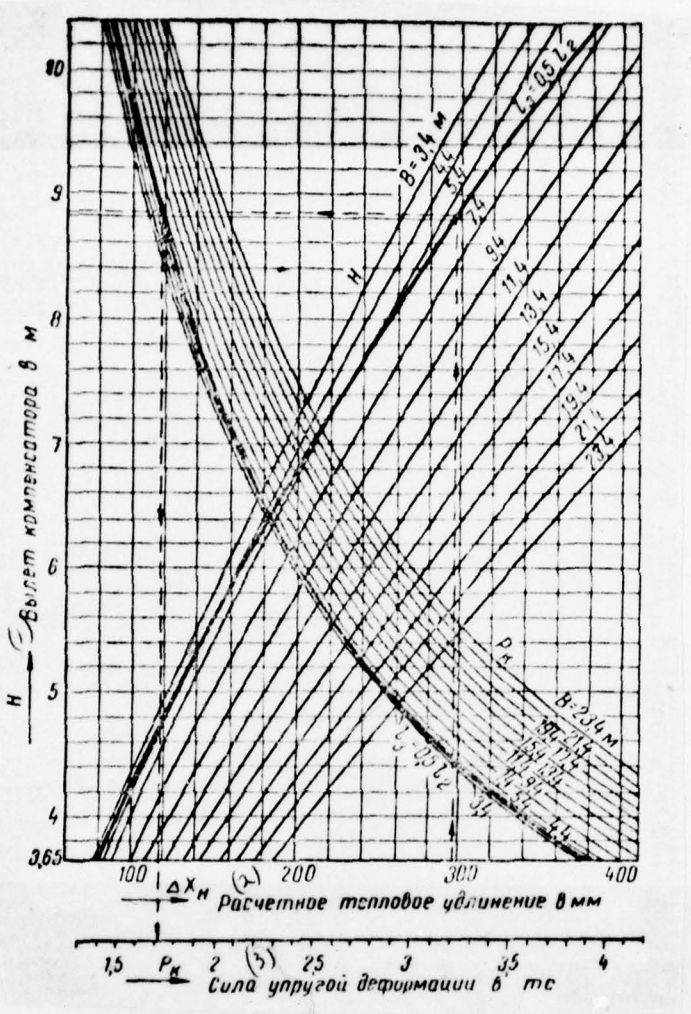


Fig. 10.68. nomogram for the calculation of U-shaped compensator with the bent smooth branch/removals

$D_н$ = 426 мм, s = 11 мм, $R_г$ = 1700 мм; W = 1451 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

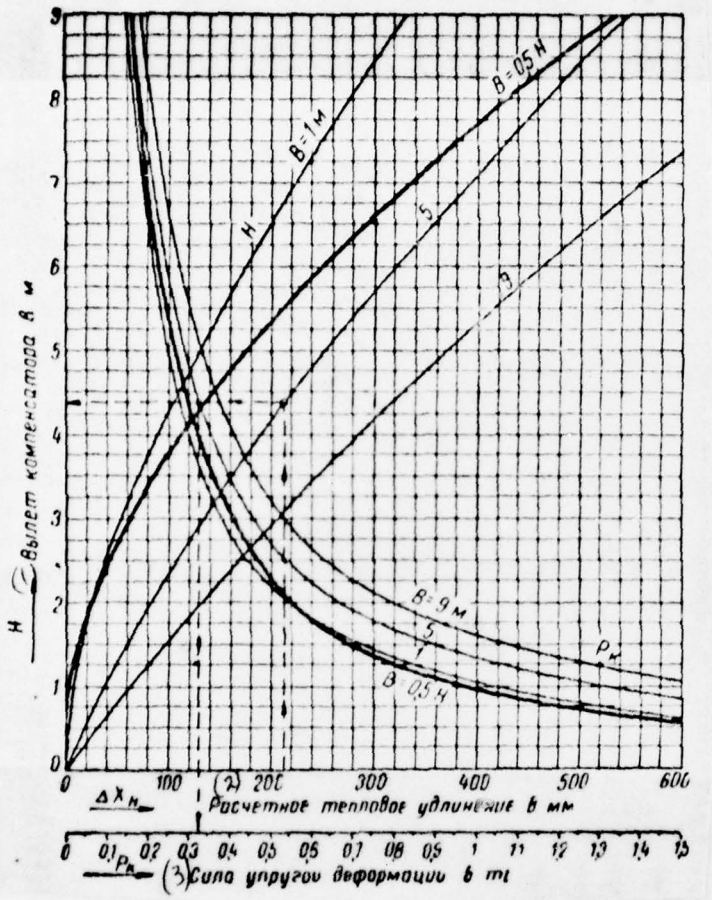


Fig. 10.69. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н = 159$ мм, $s = 4,5$ мм, $W = 82$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 223.

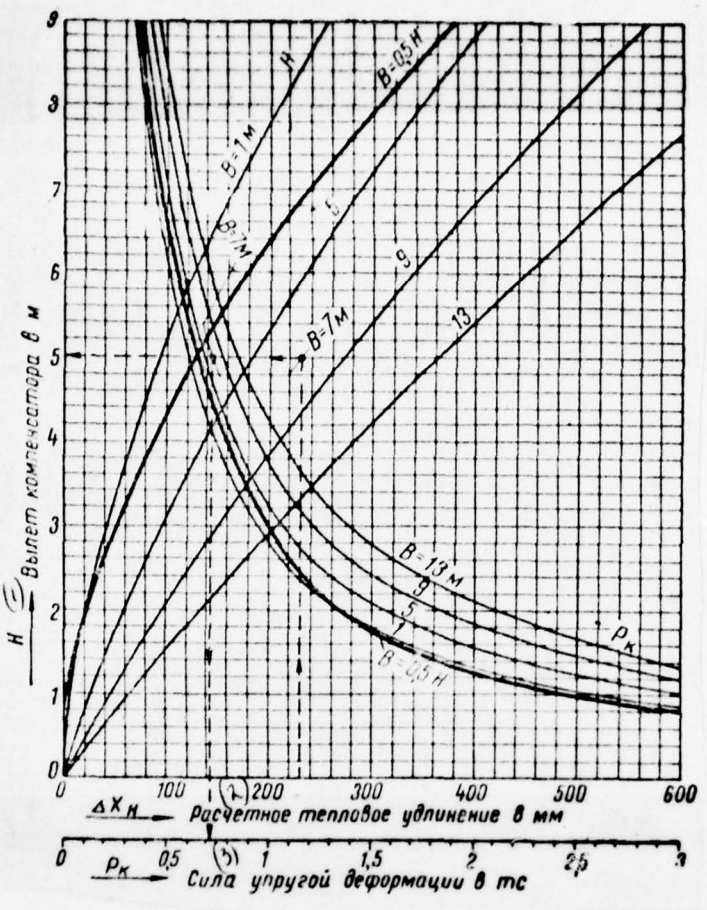


Fig. 10.70. Nomogram for calculation of U-shaped compensator with the welded branch/removals W = 208 cm^3.

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in

ton-force.

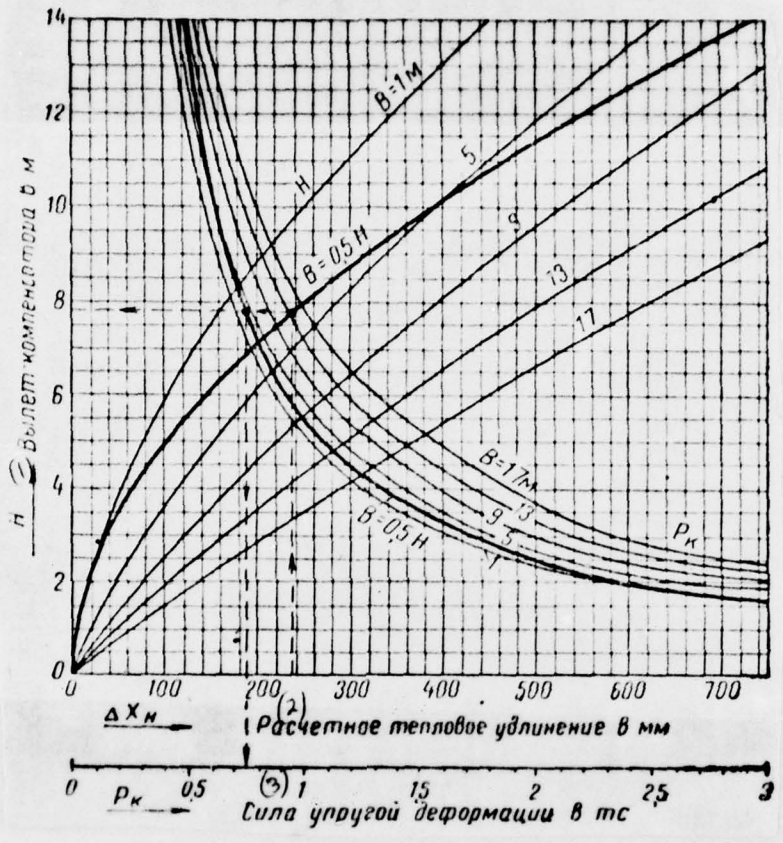


Fig. 10.71. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 273 мм; s = 7 мм; W = 379 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 224.

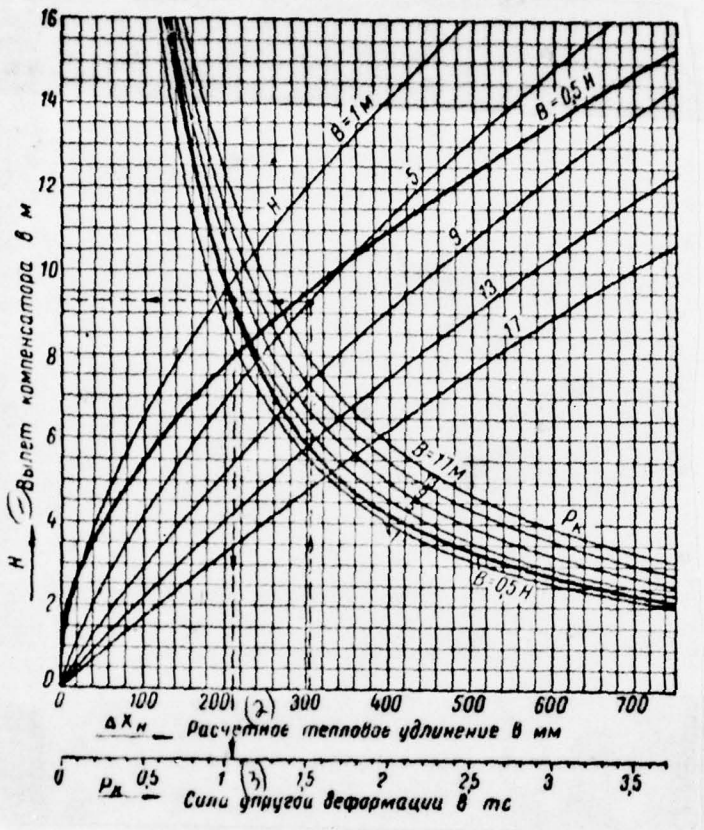


Fig. 10.72. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 325 мм; s = 8 мм; W = 616 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

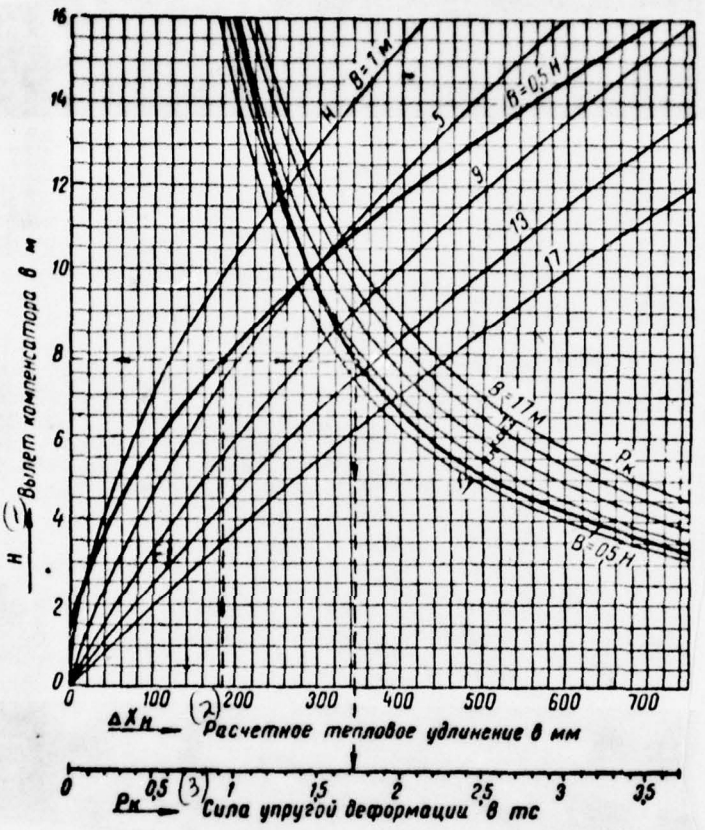


Fig. 10.73. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 377 мм; s = 9 мм; W = 935 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 225.

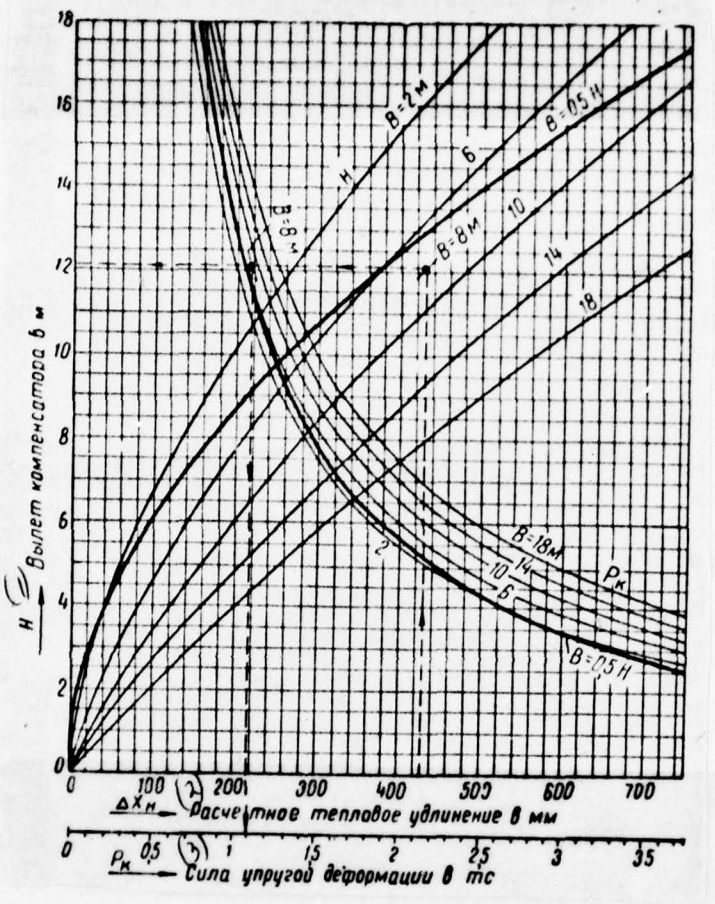


Fig. 10.74. Nomogram for the calculation of U-shaped compensator with welded branches.

$D_н$ — 426 мм; s — 6 мм; W — 819 см³

Key: (1). Span of compensator in mm. (2). Calculated

thermal elongation in mm. (3). Force of elastic deformation in ton-force.

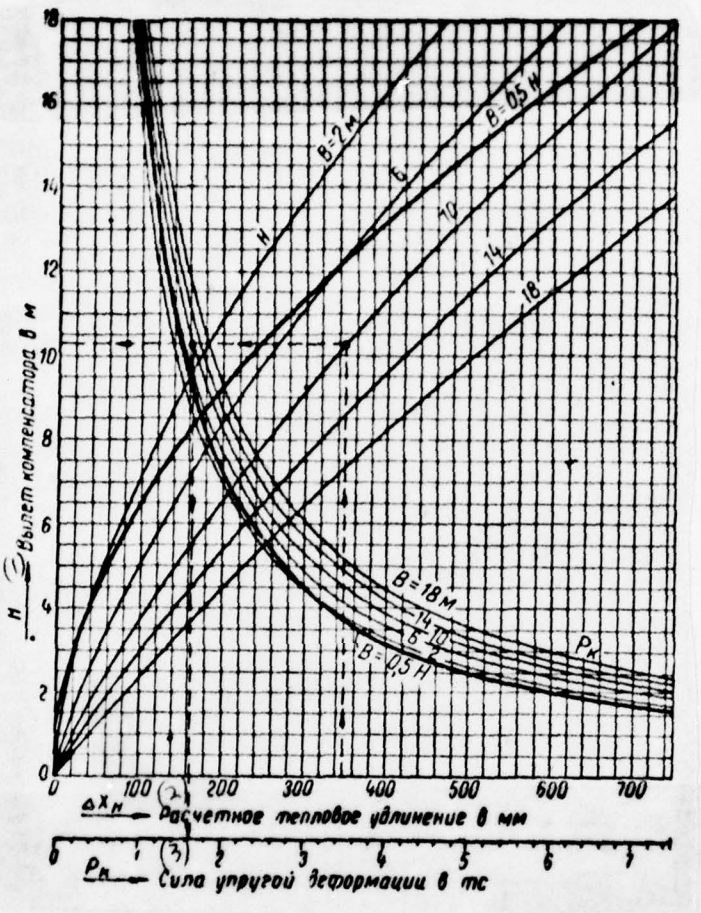


Fig. 10.75. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_в$ = 478 мм; s = 6 мм; W = 1085 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 226.

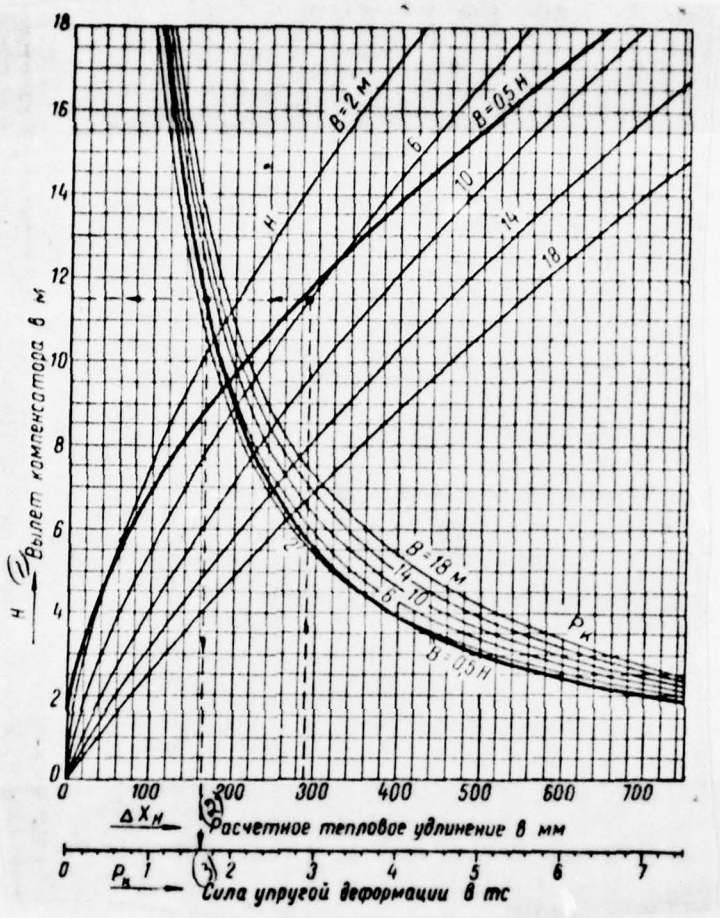


Fig. 10.76. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 529 мм; s = 6 мм; W = 127 см

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

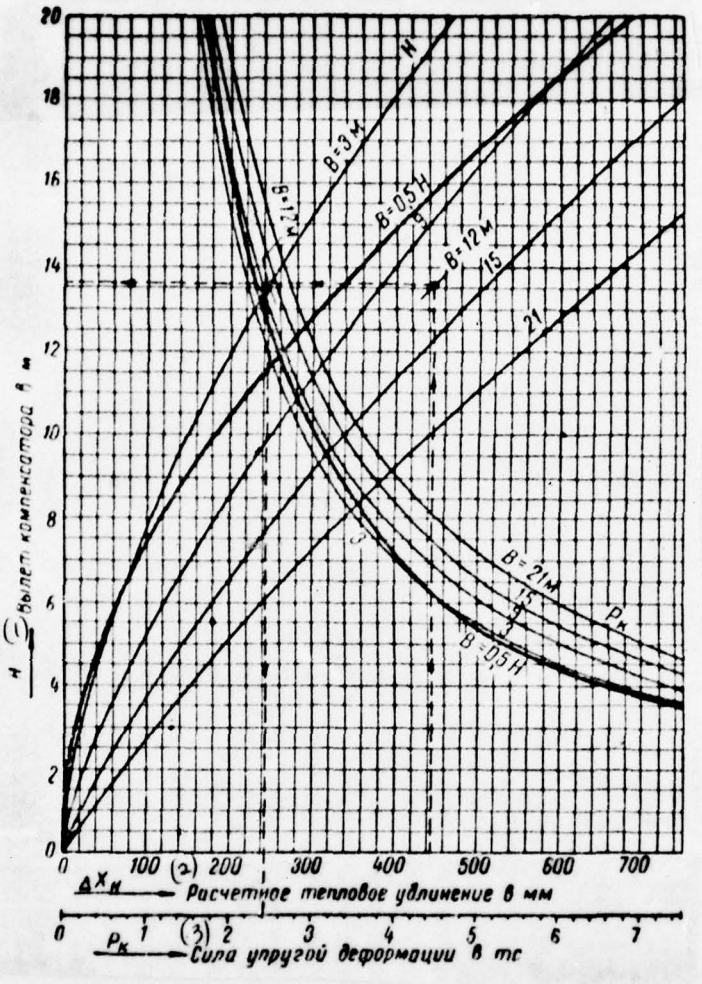


Fig. 10.77. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 630 мм, s = 7 мм W = 2109 см³

Key: (1). Span of compensator in mm. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 227.

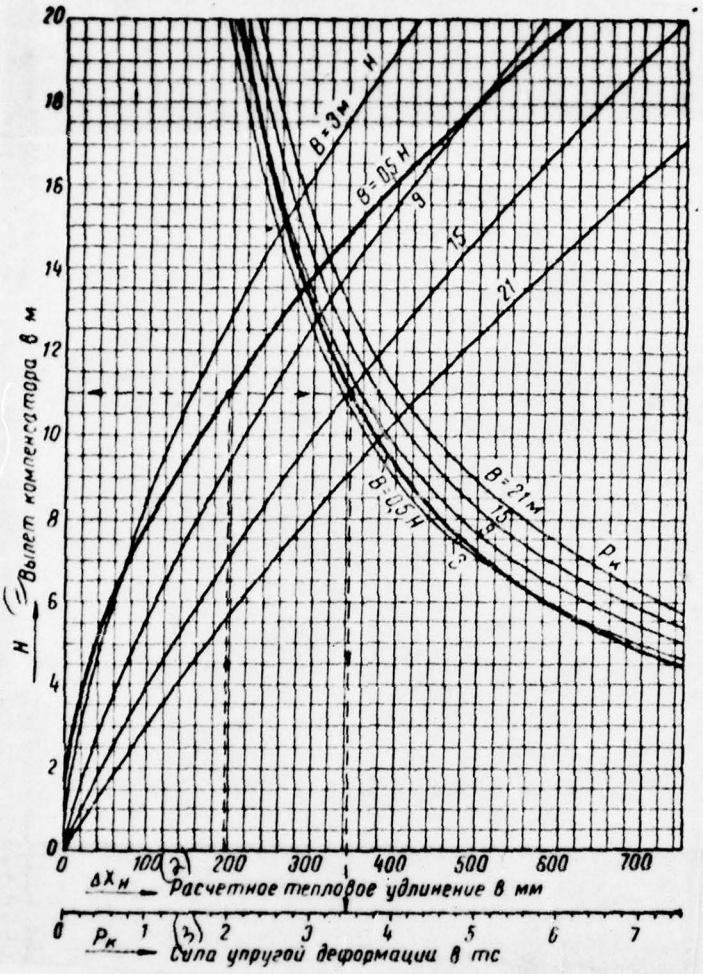


Fig. 10.78. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н = 720$ мм; $s = 7$ мм; $W = 2767$ см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

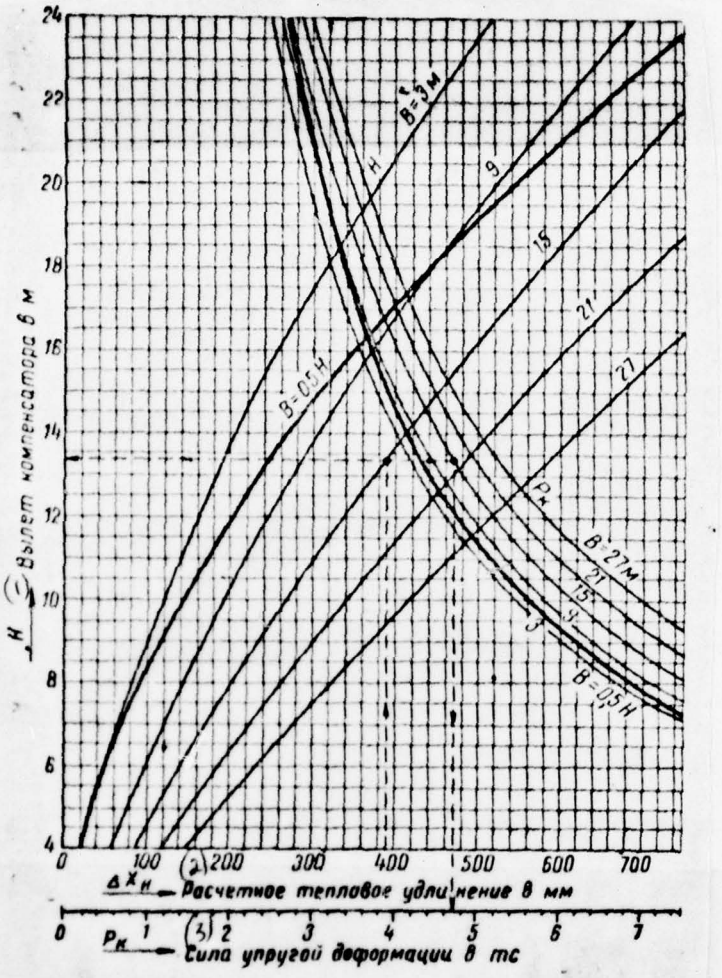


Fig. 10.79. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$=820 мм, s=8 мм, W=4100 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 228.

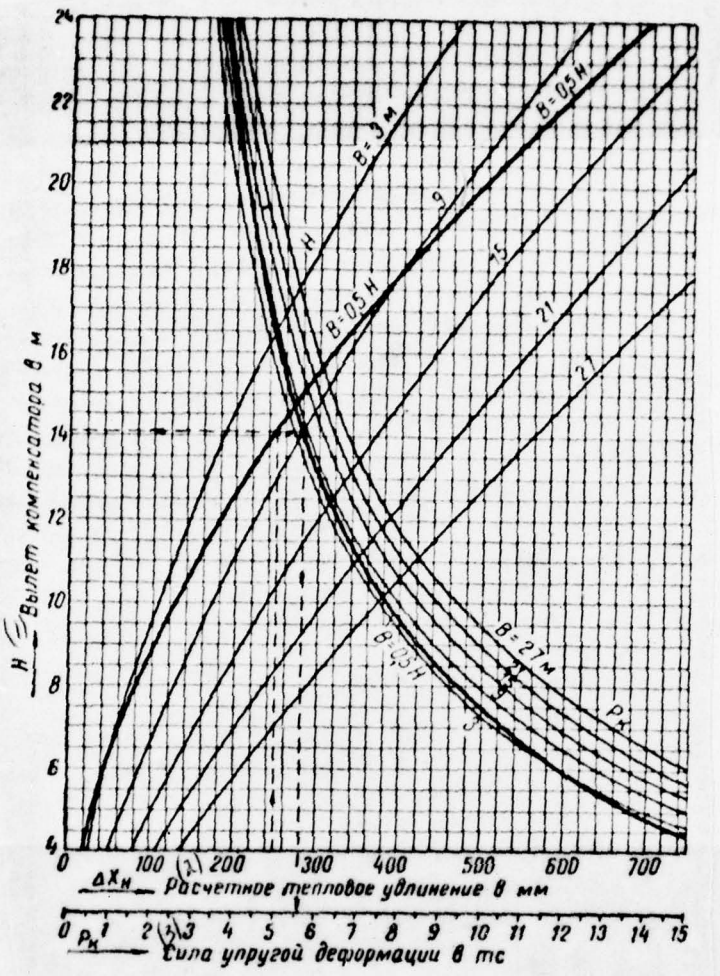


Fig. 10.80. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$ = 920 мм, s = 9 мм; W = 6811 см³

Key: (1). Span of compensator in m. (2). Calculated thermal

elongation in mm. (3). Force of elastic deformation in ton-force.

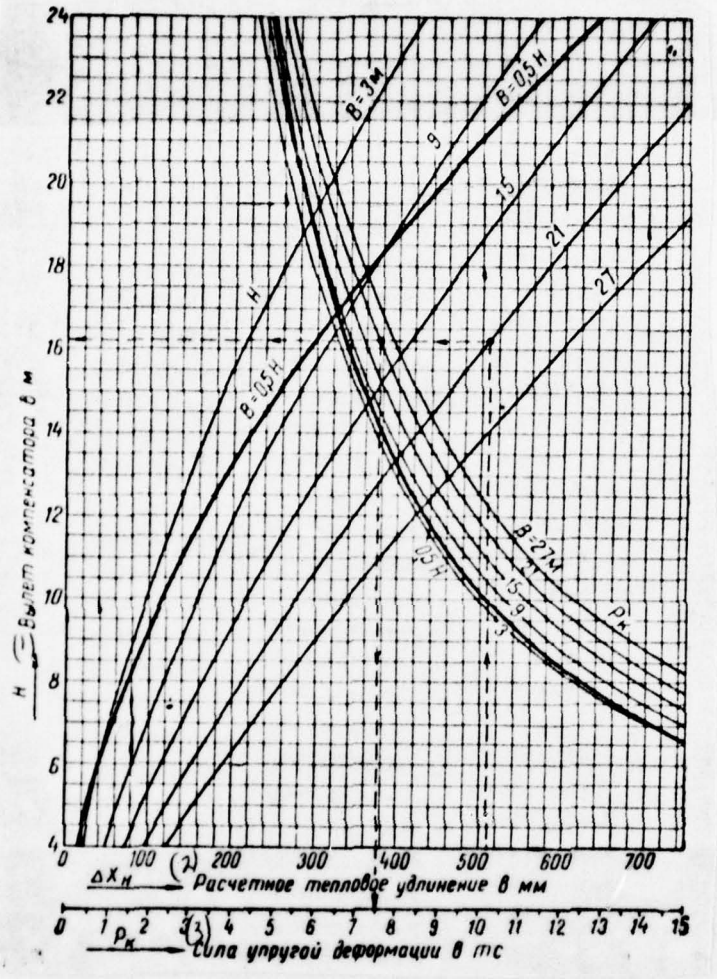


Fig. 10.81. Nomogram for the calculation of U-shaped compensator with the welded branch/removals

$D_н$=1020 мм; s=10 мм; W=7936 см³

Key: (1). Span of compensator in m. (2). Calculated thermal elongation in mm. (3). Force of elastic deformation in ton-force.

Page 229.

With the assigned/prescribed dimensions of compensator according to the scale of nomograms for calculated thermal elongation ($\Delta x_н$) they determine its calculated compensation capacity $\Delta x_{нк}$, accepting

$$\Delta x_{н.к} = \Delta x_н \text{ мм}.$$

According to the value of the calculated compensation capacity of compensator, is determined the complete thermal elongation, which can compensate for the compensator of the assigned/prescribed dimensions, by the formulas:

with amount of preliminary bracing, cluster 50o/o of complete thermal elongation:

(1) при $t < 250°C$

(2) $\Delta l = 2\Delta x_{н.к}$ мм; (10.199)

при t от 250 до 300° C

(3) $\Delta l = 1{,}67\ \Delta x_{н.к}$ мм; (10.200)

при t от 300 до 400° C

$\Delta l = 1{,}43\Delta x_{н.к}$ мм; (10.201)

Key: (1). with

with the value of the preliminary bracing, equal to 100o/o of complete thermal elongation with t $\geqslant$ 400°C

$$\Delta l = \Delta x_{н.к} \text{ мм}. \qquad (10.202)$$

The permissible distance between fixed supports is determined from the formula

$$L = \frac{\Delta l}{\alpha (t - t_{н.о})} \text{ м}. \qquad (10.203)$$

The force of elastic deformation is determined according to nomograms according to the assigned/prescribed dimensions of compensator.

If the permissible bending compensating stress on the back of compensator $\sigma'_{н.к(хол)}$ is more or less than 11 kgf/mm², the calculated compensation capacity of compensator, determined by nomogram, they recount by the formula

$$\Delta x'_{н.к} = \Delta x_{н.к} \frac{\sigma'_{н.к}}{11} \text{ мм}. \qquad (10.204)$$

and the force of elastic deformation, determined by nomograms, they recount by formula (10.198).

With the assigned/prescribed dimensions of compensator and the known value of the complete thermal elongation of

the designed section of conduit/manifold the force of elastic deformation and the bending compensating stress on the back of compensator in cold state are determined from the formulas:

$$P'_{к} = P_{к} \frac{\Delta x_{н}}{\Delta x_{н.к}} \text{ тс}; \quad (1) \qquad (10.205)$$

$$\sigma''_{н} = 11 \frac{\Delta x_{н}}{\Delta x_{н.к}} \text{ кгс/мм}^2. \quad (2) \qquad (10.206)$$

Key: (1). ton-force. (2). kgf/mm²

where $P_{к}$ is force of elastic deformation of compensator in ton-force, determined by nomogram with the assigned/prescribed dimensions of compensator;

$\Delta x_{н.к}$ is the calculated compensation capacity of compensator in mm, determined by nomogram with the assigned/prescribed dimensions of compensator;

$\Delta x_{н}$ - the calculated thermal elongation in mm, determined by formulas (10.193) is (10.196).

The bending compensating stress on the sections, adjacent to U-shaped compensator, according to nomograms they

do not determine, but they calculate in case of necessity according to formulas (10.172), (10.173) and (10.186).

At the length of the adjacent free arms, considered in calculation, not equal to the taken value during the compilation of nomograms, i.e., when $l_n < 40 D_y$, it is possible to use the given nomograms with the introduction of correction factors for the value of the compensation capacity of compensator, the force of elastic deformation and not calculated thermal elongation, which are accepted according to table (10.24).

Unknown values are determined from the formulas:

$$\Delta x'_{н.к} = \Delta x_{н.к} n_1 \text{ мм}; \quad (10.207)$$

$$\Delta x'_{н} = \frac{\Delta x_{н}}{n_1} \text{ мм}; \quad (10.208)$$

$$P'_{к} = P_{к} n_2 \text{ тс}. \quad (10.209)$$

Key: (1). ton-force.

During a change in the wall thickness of tube for U-shaped compensators with welded branch/removals, the dimensions of compensator define according to nomogram, as it is stated above, and the force of elastic deformation recount by the formula

$$P'_{\text{э}} = P_{\text{э}} \frac{W'}{W} \text{ тс}. \quad (1) \qquad (10.210)$$

Key: (1). ton-force.

where $P_{\text{э}}$ is the force of elastic deformation, determined by nomogram, in ton-force;

W - the moment of resistance of the cross section of the wall of tube with the wall thickness of the tube for which is constructed the nomogram, in cm^3;

W' - the moment of resistance of the cross section of the wall of tube with the assigned/prescribed wall thickness of tube in cm^3.

During a change in the wall thickness of tube and radii of the axle/axis of branch/removals for U-shaped compensators with the bent smooth branch/removals, it is not possible to use nomograms, but the calculation of compensator one should produce the formulas.

Chapter 11.

LOADS ON SUPPORTS OF PIPELINES.

11.1. Loads on movable supports.

Loads on mobile saddles are subdivided into vertical and horizontal and depend on the weight of the section of pipeline, which is necessary to support, and the type of support.

Vertical load is determined from the formula

$$H_0 = ql \text{ kg}, \qquad (11.1)$$

where q is weight 1 m of the pipeline: the weight of tube, insulation construction and water (weight of water for steam lines is considered in connection with the filling of

them with water during hydraulic test) in kgf;

l - the flight/span between movable supports in m.

Horizontal loads appear because of the reaction of the friction of support during its displacement/movement under the effect of the thermal elongation of pipelines and are determined from the formula

$$H_r = fql \text{ кгс}, \quad (11.2)$$

where f is the coefficient of the friction of movable supports, taken in table 11.1; q - weight 1 m of pipeline in running order: the weight of tube, insulation construction and water for water thermal grid/networks and condensate pipings (weight of water in steam lines in this case is not considered) in kgf.

where Δ - thermal displacement of strap support, arrange/located in the middle of section from fixed support to compensator, equal to the half of the thermal elongation of this section of pipeline, in mm;

Δ_r is working length of draw of strap support in mm.

During the displacement/movement of support along the

axis of the route of the straight portion of pipeline, appears only axial horizontal load $H_{r.o}$, equal to H_r.

During the displacement/movement of support at an angle to the initial axle/axis of pipeline, for example on the sections of auto/self-compensation or near flexible compensators, the horizontal load H_r they expand to two directions according to the law of right-angled triangle: axial $H_{r.o}$ - in the direction of the initial axle/axis of pipeline and side $H_{r.s}$ are perpendicular to initial axle/axis. In the absence of the data on the direction of the displacement/movement of support, it is allow/assumed to accept axial and transverse loads each equal to $0.7H_r$. With displacement of support, it is perpendicular to the initial axle/axis of pipeline, for example on the back of flexible compensators, appears only side horizontal load $H_{r.s}$, equal to H_r.

During the arrangement/position of movable support in the unit of pipelines, additionally are considered the weight of reinforcement, gasket compensators, and also the weight of the adjacent sections of the branches, which are necessary to this support. The weight of branches is determined from formula (11.1), but with coefficient of 0.5,

that considers weight distribution between two dispites.

For decrease in the vertical load on movable support, is reduced flight/span 1 between the examined/considered and nearest to it supports on main line and branches.

11.2. Loads to fixed supports.

Loads on fixed saddles are subdivided into vertical and horizontal.

Vertical loads are determined from formula (11.1). If fixed support is placed in the unit of pipelines, the account of increment loads from reinforcement, gasket compensators, etc. is produced by analogy with movable supports.

Horizontal loads on the fixed supports of pipelines appear under the effect of the following forces:

friction in mobile supports during the thermal elongation of the pipeline, laid in impassable and

semiaccess channels, tunnels it is above-grade:

friction in gasket compensators during the thermal elongation of pipeline;

elastic deformation of flexible compensators or auto/self-compensation with their extension in cold state or during the thermal elongation of pipeline;

internal pressure during the application/use of the unbalanced gasket compensators (cut pipelines).

During the application/use of the bent compensators of the force of internal pressure, they are absorbed by pipeline and to fixed support are not transferred.

During setting up on an entire route of the balanced gasket compensators of the force of internal pressure, they are balanced by the very construction of compensator and also they are not transferred to fixed support.

Table 11.1. Coefficient of the friction of movable supports.

(1) Тип опор	(2) Коэффициент трения подвижных опор f
(3) Скользящие	0,3
(4) Катковые при осевом перемещении трубопровода	0,1
(5) Катковые при боковом перемещении трубопровода перпендикулярно оси	0,3
(6) То же, под углом к оси	0,15—0,2
(7) Подвесные	0,1

Note. During the known construction of strap support the coefficient of friction is determined from the formula

$$f = \frac{\Delta}{h_т}.$$

Key: (1). Type of supports. (2). Coefficient of the friction of movable supports f. (3). Sliding. (4). Roller during the axial displacement of pipeline. (5). Roller during the side displacement of pipeline are perpendicular to axle/axis. (6). The same, at an angle to axle/axis. (7) Suspension.

Page 231.

Forces of friction in movable supports are determined from the formula

$$T_{тр}^{оп} = fqL \text{ кгс}, \qquad (11.3)$$

where q is weight 1 m of pipeline in running order in kgf;

L = the length of pipeline from fixed support to compensator or from fixed support to the rotation (during auto/self-compensation) in m.

Forces of friction in gasket compensators are determined depending on the operating pressure of heat carrier, diameter of tube and construction of gasket packing according to the formulas:

$$P_c = 2P_{раб} l_2 D_2 f\pi \text{ кгс}. \quad (11.4)$$

$$P_c = \frac{4 P_{раб}}{f_n} l_2 D_2 f\pi \text{ кгс}. \quad (11.5)$$

[кгс = kg]

In these formulas:

$P_{раб}$ - the operating pressure of heat carrier in kg/cm²; l_2 - length of a layer of packing along the axis of gasket compensator in cm; D_2 is a outside diameter of the beaker/sleeve of gasket compensator in cm; f - the coefficient of the friction of packing against metal are taken as equal to 0.15; n - the number of bolts of compensator; f_n is an area of transverse section of packing in cm².

The cross-sectional area of packing is determined from

the formula

$$f_н = 0{,}785\,(D_з^2 - D_т^2)\ см^2, \qquad (11.6)$$

where $D_з$ is a bore of the housing of gasket compensator in cm.

During determination P_c from formula (11.5) value $\frac{4000n}{f_н}$ is taken not less than 10 kg/cm². As calculated they accept large of forces P_c obtained formulas (11/4) and (11.5).

For determining forces of friction in gasket compensators, it is possible to use graph Fig. of 11.1.

The forces of elastic deformation of flexible compensators and sections of auto/self-compensation are determined during the calculation of tubes for the compensation for thermal elongations in accordance with the indications of chapter 10.

The forces of internal pressure are transferred only to those fixed supports which are arrange/located between the unbalanced gasket compensator and the rotation of tube, between two adjacent sections with the different diameters of gasket compensators (transition of the diameters of

tubes), on section with catch (with its coverage) or with plug/silencer.

For the cases of the arrangement/position of support on section with the rotation of tube, with plug/silencer or catch of the force of internal pressure they determine from the formula

$$P_{в.д} = P_{раб} F_{с.н} \text{ кгс}, \qquad (11.7)$$

where $P_{раб}$ is the operating pressure of heat carrier in kg/cm²; $F_{с.н}$ is a cross-sectional area throughout the outside diameter of the beaker/sleeve of gasket compensator in cm².

For the case with the transition of the diameters of tubes the force of internal pressure is determined from the formula

$$P_{в.д} = P_{раб} (F_{с.н1} - F_{с.н2}) \text{ кгс}. \qquad (11.8)$$

where $F_{с.н1}$ is an area according to the outside diameter of the beaker/sleeve of the gasket compensator of larger diameter in cm²; $F_{с.н2}$ is the same, smaller diameter in cm².

Force direction - to the side of the smaller diameter of pipeline.

The forces of internal pressure for gasket compensators can be accepted according to the graphs of Fig. 11.2 and 11.3.

In formulas (11.4), (11.7) and (11.8) the value of operating pressure $P_{раб}$ is taken:

for steam lines - on initial pressure pair on the collector/receptacle of source of heat;

for the delivery pipe of water thermal grid/networks - on the greatest pressure in pipeline taking into account the difference in the marks of the earth/ground in route;

for reverse/inverse - in the greatest possible pressure in pipeline during the different operating modes taking into account area relief on the route of thermal grid/network, but not less than 10 kg/cm^2;

for composite condensate pipings - on pressure the pair before the drainage controller;

for forcing condensate pipings - on the greatest pressure in pipeline taking into account the difference in marks.

Table 11.2 gives the summary of calculated formulas for determining the forces, which affect fixed supports.

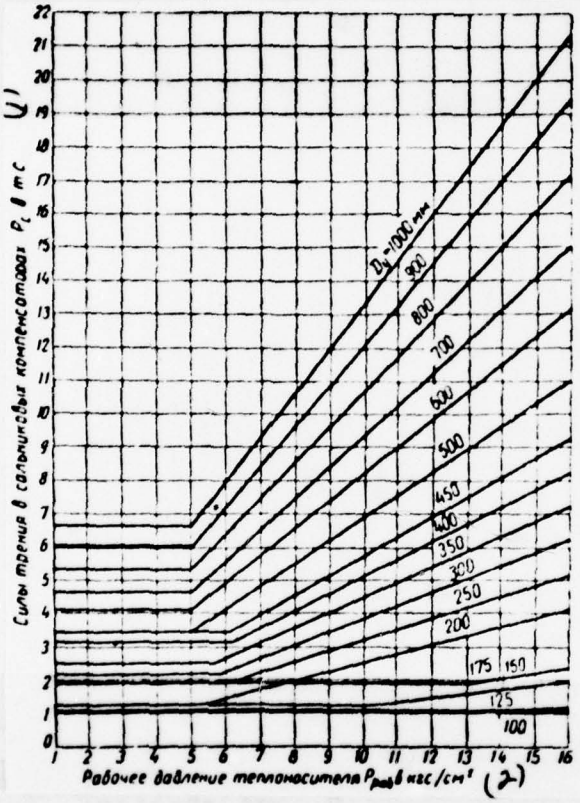


Fig. 11.1. Nomogram for determining forces of friction in the gasket compensators

Key: (1). Forces of friction in the gasket compensators P_c in ton-force. (2). The operating pressure tof heat-transfer agent $P_{раб}$ in kg/cm².

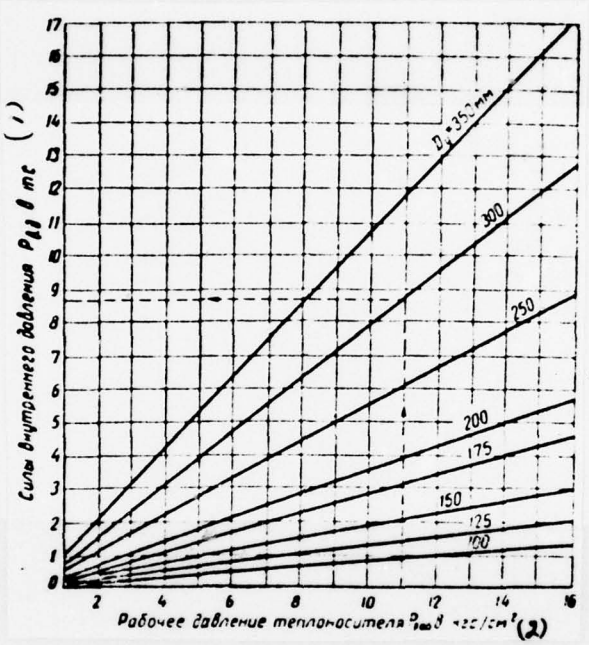

Силы внутреннего давления $P_{вд}$ в тс (1)
Рабочее давление теплоносителя $P_{раб}$ в кгс/см² (2)
D_y = 350 мм
300
250
200
175
150
125
100

Fig. 11.2.

Page 232.

Fig. 11.2. Graph for determining he forces of the internal pressure $P_{в.д}$ with gasket compensators for D_y = 100-350 mm.

Key: (1). orces of the internal pressure $P_{в.д}$ in ~~kg~~ ts. (2). The operating pressure of heat-transfer agent $P_{раб}$ in kg/cm².

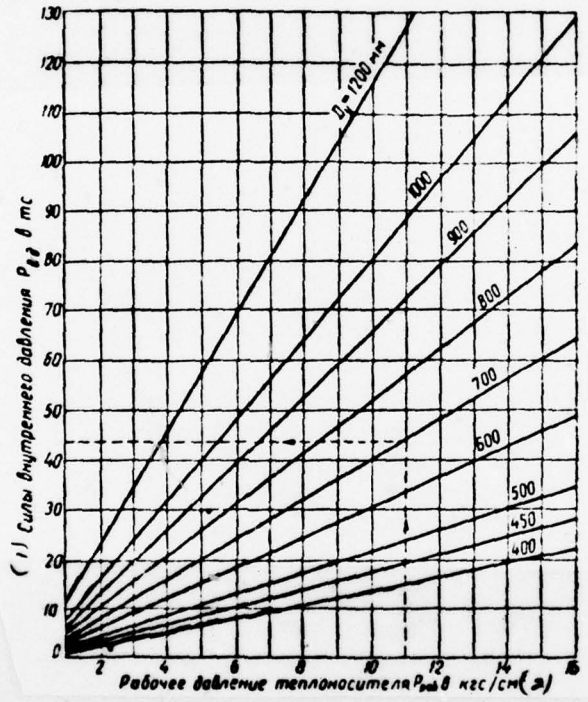


Fig. 11.3. graph for determining ache forces of the internal pressure $P_{в.д}$ with gasket compensators for D_y = 400-1000 mm.

Key: (1). Forces of the internal pressure $P_{в.д}$ in ms. (2). The operating pressure of heat-transfer agent $P_{раб}$ in kg/cm^2.

Tables 11.2. The summary table of calculated formulas for determining the forces, which effect on fixed saddles.

(1) Наименование нагрузок	(2) Фактор, вызывающий появление сил	(3) Наименование сил	(4) Расчетные формулы: (5) трубопровод неразрезанный	(6) трубопровод разрезанный	(7) Примечания
Вертикальные (8)	Вес трубопровода (9)	Силы веса (10)	$H_в = ql$ кгс (14)		–
Горизонтальные (осевые боковые (11)	Температурное удлинение трубопроводов (12)	Силы трения в подвижных опорах (13)	$P_{тр}^{оп} = lqL$ кгс (14)		–
		Силы упругой деформации при самокомпенсации (15)	P_x; P_y в кгс (14)		(15) Определяют расчетом труб на компенсацию тепловых удлинений (глава 10)
		Силы упругой деформации при П- и S-образных компенсаторах (16)	$P_к$ в кгс (14)		
		Силы трения в сальниковых компенсаторах (18)	–	$P_с = 2P_{раб} f \pi l_1 D_2$ кгс (14) или (19) $P_с = \frac{400n}{l_н} f \pi l_1 D_2$ кгс (14)	(20) В расчете учитывают большую из полученных сил
	Внутреннее давление (21)	Неуравновешенные силы внутреннего давления (22)	–	$P_{в.д} = P_{раб} F_{с.н}$ кгс (14)	–

Key: (1). Designation of loads. (2). The factor, calling is the Appearance of forces. (3). Designation of forces. (4). Calculated formulas. (5). pipeline continued. (6). pipeline cut. (7). Notes. (8). Vertical. (9). Weight of pipeline. (10). Gravitational forces. (11). Horizontal (axial side). (12). Temperature elongation of pipelines. (13). forces of friction in mobile supports. (14). kgf. (15). forces of elastic deformation with self-compensation. (16). Forces of elastic deformation with U- and S-shaped compensators. (17).

Is calculated of tubes for the compensation for thermal elongations (chapter 10). (18). Forces of friction in gasket compensators. (19). or. (20). In calculation they consider large of the obtained forces. (21). Internal pressure. (22). The unbalanced forces of internal pressure.

[B = in]

Page 233.

Horizontal loads on fixed supports are subdivided into **axial** $H_{r.o}$ **those who** effect along the axis of pipeline, and **side** $H_{r.б}$ **- are** perpendicular to axle/axis. Axial loads are transferred to all the fixed supports, side - to the fixed supports, which are placed in the units of branches. Furthermore, transverse loads are transferred with displacement of support directly before the rotation of tube with self-compensation, and also with displacement of fixed support on to the angle of rotation of tube. For these supports the forces, which affect along the axis of pipelines, they expand to two those who comprise - along the axle/axis of fixed support it is perpendicular to it.

Fixed supports are subdivided into end, that are placed before plug/silencer or the rotation, i.e., at the end of

the section of pipeline, and intermediates, that are placed between two adjacent sections.

On end fixed supports horizontal axial loads are determined according to the sum of the forces, which affecting support on the one hand.

Horizontal axial loads on inner bearings are determined taking into account all acting forces on both sides of support. In this case, are examined all the possible conditions/modes of the work of the pipeline: from the cold to working order (at the calculated temperature of heat carrier) - heating and from working of the cold state of pipeline - cooling; this is connected with the fact that forces of friction and force of elastic deformation of flexible compensators and angles of rotation of tubes change their direction during heating and during cooling.

For the facilitation of the analysis of the values of the loads, which effect on fixed support during the different conditions/modes of the work of pipeline, one should construct the diagram/curves of each of the acting forces.

During the determination of horizontal axial load on support for each conditions/mode of the work of the pipeline of the forces, which effect on fixed support in one direction, they store/add up, and then from the larger sum of forces deduct smaller; in this case, taking into account probable deviations from calculated values, forces of friction and force of elastic deformation they deduct with coefficient of 0.7 how it is provided a certain reserve in design load on fixed support.

With the equality of the sum of the forces, which affect support from both sides, as calculated is accepted one of the sums with coefficient of 0.3.

The maximum value of horizontal loads on supports are obtained near marginal conditions of the work of pipeline (beginning and the end of the heating and cooling). In connection with this calculation formulas comprise only for these four conditions/modes. As calculated horizontal axial load they accept maximum of the obtained loads.

For illustration is given an example of the determination of the horizontal axial load, which effects on intermediate fixed support, for the circuit of the section

of pipeline, given to Fig. 11.4, with the U-shaped 16-100 compensator, carried out with preliminary bracing in cold state to the half of the complete thermal elongation of section, and the L-shaped section of auto/self-compensation, carried out without preliminary bracing in cold state. The calculated temperature of heat carrier t = 150°C.

The determinations of horizontal axial loads on support from the diagram/curve of forces (Fig. 11.5) compose calculation formulas for basic four conditions/modes.

Conditions/mode I:

$$H_{r.o} = P_к + fq_2 L_2 - 0{,}7 fq_1 L_1 ; \quad (11.9)$$

either

$$H_{r.o} = fq_1 L_1 - 0{,}7 (P_к + fq_2 L_2) . \quad (11.10)$$

conditions/mode II:

$$H_{r.o} = P_к + fq_1 L_1 - 0{,}7 (P_x + fq_2 L_2) ; \quad (11.11)$$

or

$$H_{r.o} = P_x + fq_2 L_2 - 0{,}7 (P_к + fq_1 L_1) . \quad (11.12)$$

conditions/mode III:

$$H_{r.o} = P_x + fq_1 L_1 - 0{,}7 (P_к + fq_2 L_2) ; \quad (11.13)$$

either

$$H_{r.o} = P_к + fq_2 L_2 - 0{,}7 (P_x + fq_1 L_1) . \quad (11.14)$$

conditions/mode IV:

$$H_{r.o} = P_к + fq_1 L_1 - 0{,}7 fq_2 L_2 \quad (11.15)$$

or

$$H_{г.ф} = fq_2 L_2 - 0{,}7 (P_н + fq_1 L_1). \quad (11.16)$$

The analysis of the obtained calculation formulas shows that the value of load on fixed support of formulas (11.10); (11.11); (11.14); (11.16) turns out considerably less than by formulas (11.9), (11.12), (11.13) and (11.15). Therefore calculation is produced only by last/latter four formulas. Design load it will be greatest of four obtained values.

If about fixed support is establish/installed close fitting valve, horizontal axial load on support is determined with the open and closed reinforcement.

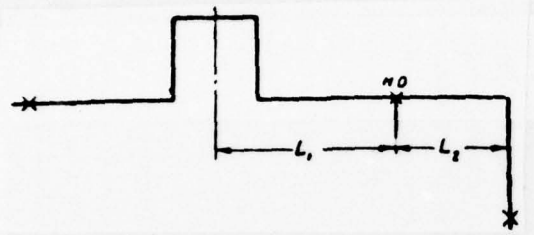


Fig. 11.4.

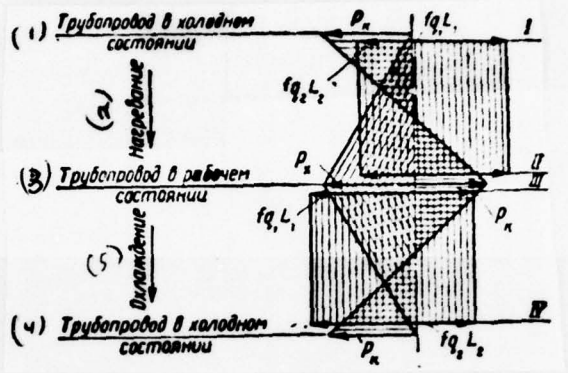


Fig. 11.5.

Fig. 11.4. Diagram of calculated section with U-shaped compensator.

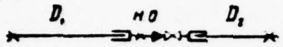
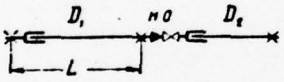
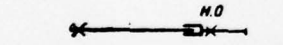
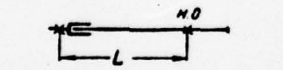
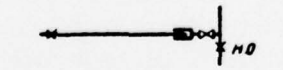
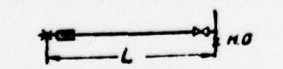
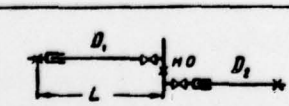
Fig. 11.5. The diagram/curves of the forces, which affect fixed support, for the different conditions/modes of the work of the pipeline

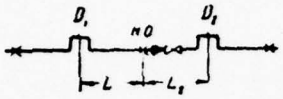
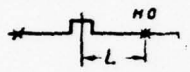
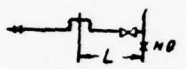
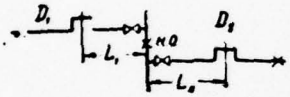
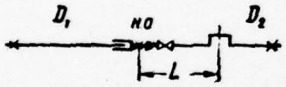
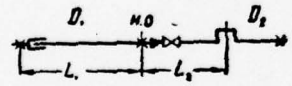
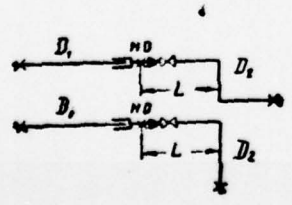
I - will begin heatings; II - the end of the heating; III - the beginning of cooling; IV is an end of the cooling.

Key: (1) (4) Pipeline in cold state; (2) Heating; (3) Pipeline in working condition; (5) Cooling.

page 234.

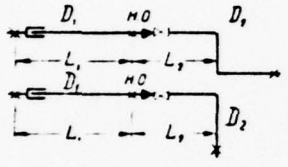
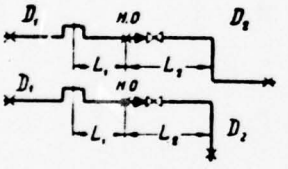
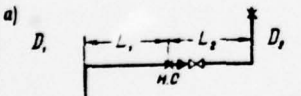
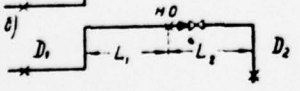
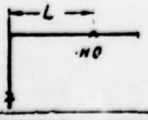
Tables 11.3. Calculation formulas for determination and horizontal axial $H_{г.о}$ and side $H_{г.б}$ loads on fixed saddles.

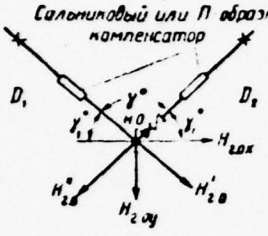
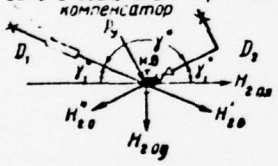
№ схем (3)	(2) Схема расчетного участка трубопровода	(8) Расчетные формулы		
		(4) для схем без задвижек или при открытых задвижках	(5) при закрытых задвижках	
			лучевые схемы тепловых (6) сетей	кольцевые схемы тепловых (7) сетей при $D_1 \approx D_2$
1		$D_1 > D_2$ $H_{г.о} = P_{c1} - 0{,}7P_{c2} + P_{раб}(F_{с.н1} - F_{с.н2})$ $D_1 = D_2$ $H_{г.о} = 0{,}3P_c$	$H_{г.о} = P_{c1} + P_{раб} F_{с.н1}$ $H_{г.о} = P_{c2} + P_{раб} F_{с.н2}$	$H_{г.о} = P_{c1} + P_{c2} + P_{раб} F_{с.н1}$
2		$D_1 > D_2$ $H_{г.о} = P_{c1} + fq_1 L_1 + P_{раб}(F_{с.н1} - F_{с.н2}) - 0{,}7(P_{c2} + fq_2 L_2)$ $H_{г.о} = P_{c2} + fq_2 L_2 + P_{раб}(F_{с.н1} - F_{с.н2}) - 0{,}7(P_{c1} + fq_1 L_1)$ $D_1 = D_2$, $L_1 = L_2 = L$ $H_{г.о} = 0{,}3(P_c + fqL)$	$H_{г.о} = P_{c1} + fq_1 L_1 + P_{раб} F_{с.н1}$ $H_{г.о} = P_{c2} + fq_2 L_2 + P_{раб} F_{с.н2}$	$H_{г.о} = P_{c1} + P_{c2} + fq_1 L_1 + fq_2 L_2 + P_{раб} F_{с.н1}$
3		$D_1 > D_2$ $H_{г.о} = P_{c1} - 0{,}7P_{c2} + fq_1 L + P_{раб}(F_{с.н1} - F_{с.н2})$ $D_1 = D_2$ $H_{г.о} = 0{,}3P_c + fqL$	$H_{г.о} = P_{c1} + fq_1 L + P_{раб} F_{с.н1}$ $H_{г.о} = P_{c2} + P_{раб} F_{с.н2}$	$H_{г.о} = P_{c1} + P_{c2} + fq_1 L + P_{раб} F_{с.н1}$
4		$H_{г.о} = P_c + P_{раб} F_{с.н}$	–	–
5		$H_{г.о} = P_c + P_{раб} F_{с.н} + fqL$	–	–
6		$H_{г.б} = P_c + P_{раб} F_{с.н}$	$H_{г.б} = P_c + P_{раб} F_{с.н}$	–
7		$H_{г.б} = P_c + P_{раб} F_{с.н} + fqL$	$H_{г.б} = P_c + P_{раб} F_{с.н} + fqL$	–
8		$H_{г.б} = P_{c1} + fq_1 L + P_{раб} F_{с.н1}$ $H_{г.б} = P_{c2} + P_{раб} F_{с.н2}$	$H_{г.б} = P_{c1} + fq_1 L_1 + P_{раб} F_{с.н1}$ $H_{г.б} = P_{c2} + P_{раб} F_{с.н2}$	–

№ схем (1)	Схема расчетного участка трубопровода (2)	Расчетные формулы (3)		
		для схем без задвижек или при открытых задвижках (4)	при закрытых задвижках (5)	
			лучевые схемы тепловых сетей (6)	кольцевые схемы тепловых сетей при $D_1 \geq D_2$ (7)
9		$D_1 > D_2$ $H_{г.о} = P_{к1} + fq_1 L_1 - 0{,}7 (P_{к2} + fq_2 L_2)$ $H_{г.о} = P_{к2} + fq_2 L_2 - 0{,}7 (P_{к1} + fq_1 L_1)$ $D_1 = D_2$; $L_1 = L_2 = L$ $H_{г.о} = 0{,}3 (P_к + fqL)$	$H_{г.о} = P_{к1} + fq_1 L_1$ $H_{г.о} = P_{к2} + fq_2 L_2$	$H_{г.о} = P_{к1} + P_{к2} + fq_1 L_1 + fq_1 L_2$
10		$H_{г.о} = P_к + fql$	–	–
11		$H_{г.б} = P_к + fqL$	$H_{г.б} = P_к + fqL$	–
12		$H_{г.б} = P_{к1} + fq_1 L_1$ $H_{г.б} = P_{к2} + fq_2 L_2$	$H_{г.б} = P_{к1} + fq_1 L_1$ $H_{г.б} = P_{к2} + fq_2 L_2$	–
13		$D_1 > D_2$ $H_{г.о} = P_с + P_{раб} F_{с.н} + P_к - 0{,}7 fq_2 L$ $H_{г.о} = fq_2 L + P_{раб} F_{с.н} + P_к - 0{,}7 P_с$	$H_{г.о} = P_с + P_{раб} F_{с.н}$ $H_{г.о} = P_к + fq_2 L$	$H_{г.о} = P_с + P_к + P_{раб} F_{с.н} + fq_2 L$
14		$D_1 > D_2$ $H_{г.о} = P_с + fq_1 L_1 + P_{раб} F_{с.н} + P_к - 0{,}7 fq_2 L_2$	$H_{г.о} = P_с + fq_1 L_1 + P_{раб} F_{с.н}$ $H_{г.о} = P_к + fq_2 L_2$	$H_{г.о} = P_с + fq_1 L_1 + P_{раб} F_{с.н} + P_к + fq_2 L_2$
15		при $t < 250°C$ $H_{г.о} = P_{раб} F_{с.н} + fq_2 L - 0{,}7 P_с$ $H_{г.о} = P_{раб} F_{с.н} + P_с - 0{,}7 fq_2 L$ при $t > 250°C$ $H_{г.о} = P_{раб} F_{с.н} + fq_2 L + P_х - 0{,}7 P_с$ $H_{г.о} = P_{раб} F_{с.н} + P_с + P_х - 0{,}7 fq_2 L$ $H_{г.б} = P_у$	$H_{г.о} = P_с + P_{раб} F_{с.н}$ $H_{г.о} = P_х + fq_2 L$ $H_{г.б} = P_у$	$H_{г.о} = P_с + P_{раб} F_{с.н} + fq_2 L + P_х$ $H_{г.б} = P_у$

page 236.

Table 11.3 is continued.

(1) № схем	(2) Схема расчетного участка трубопровода	(3) Расчетные формулы		
		для схем без задвижек или при открытых задвижках (4)	(5) при закрытых задвижках: двухлучевые схемы тепловых (6) сетей	(5) при закрытых задвижках: кольцевые схемы тепловых (7) сетей при $D_1 > D_2$
16		при $t \leq 250$°С $H_{г.о} = P_{раб} F_{с.н} + fq_2 L_2 - 0{,}7 (P_c + fq_1 L_1)$ $H_{г.о} = P_{раб} F_{с.н} + P_c + fq_1 L_1 - 0{,}7 fq_2 L_2$ при $t > 250$°С $H_{г.о} = P_{раб} F_{с.н} + P_c + P_x + fq_1 L_1 - 0{,}7 fq_2 L_2$ $H_{г.о} = P_{раб} F_{с.н} + P_x + fq_2 L_2 - 0{,}7 (P_c + fq_1 L_1)$ $H_{г.б} = P_y$	$H_{г.о} = P_c + P_{раб} F_{с.н} + fq_1 L_1$ $H_{г.о} = P_x + fq_2 L_2$ $H_{г.б} = P_y$	$H_{г.о} = P_c + P_{раб} F_{с.н} + fq_1 L_1 + P_x + fq_2 L_2$ $H_{г.б} = P_y$
12		$H_{г.о} = P_к + fq_1 L_1 - 0{,}7 fq_2 L_2$ $H_{г.о} = P_к + fq_2 L_2 - 0{,}7 fq_1 L_1$ дополнительно при $t \leq 250$°С $H_{г.о} = P_x + fq_2 L_2 - 0{,}7 (P_к + fq_1 L_1)$ $H_{г.о} = P_x + fq_1 L_1 - 0{,}7 (P_к + fq_2 L_2)$ дополнительно при $t > 250$°С $H_{г.о} = P_x + fq_2 L_2 - 0{,}7 fq_1 L_1$ $H_{г.о} = P_x + fq_1 L_1 - 0{,}7 fq_2 L_2$ $H_{г.б} = P_y$	$H_{г.о} = P_к + fq_1 L_1$ $H_{г.о} = P_x + fq_2 L_2$ $H_{г.б} = P_y$	$H_{г.о} = P_к + P_x + fq_1 L_1 + fq_2 L_2$
18	а)  б) 	$H_{г.о} = P_{x1} + fq_1 L_1 - 0{,}7 (P_{x2} + fq_2 L_2)$ $H_{г.о} = P_{x2} + fq_2 L_2 - 0{,}7 (P_{x1} + fq_1 L_1)$ $H_{г.о} = P_{x1} + fq_2 L_2 - 0{,}7 (P_{x2} + fq_1 L_1)$ $H_{г.о} = P_{x2} + fq_1 L_1 - 0{,}7 (P_{x1} + fq_2 L_2)$ для схемы 18 *а* $H_{г.б} = P_{y1} - 0{,}7 P_{y2}$ или $H_{г.б} = P_{y2} - 0{,}7 P_{y1}$ для схемы 18*б* $H_{г.б} = P_{y1} + P_{y2}$	$H_{г.о} = P_{x1} + fq_1 L_1$ $H_{г.о} = P_{x2} + fq_2 L_2$ $H_{г.б} = P_{y1}$ $H_{г.б} = P_{y2}$	$H_{г.о} = P_{x1} + P_{x2} + fq_1 L_1 + fq_2 L_2$ $H_{г.б} = P_{y1} + P_{y2}$
19		$H_{г.о} = P_x + fqL$ $H_{г.б} = P_y$	–	–

(1) № схем	(2) Схема расчетного участка трубопровода	(3) Расчетные формулы: (4) для схем без задвижек или при открытых задвижках	(3) при закрытых задвижках: (5) лучевые схемы тепловых сетей	(6) кольцевые схемы тепловых сетей при $D_1 \geq D_2$
20	(9) Сальниковый или П образный компенсатор 	(8) Неподвижная опора расположена по биссектрисе угла γ: $\gamma_1 = \frac{180-\gamma}{2}$; $H_{г.ox} = H_{г.o} \cos\gamma_1$; $H_{г.oy} = H_{г.б} = (H'_{г.o} + H''_{г.o}) \sin\gamma_1$	$H_{г.ox} = H'_{г.o} \cos\gamma_1$; $H_{г.oy} = H_{г.б} = H'_{г.o} \sin\gamma_1$; $H_{г.ox} = H''_{г.o} \cos\gamma_1$; $H_{г.oy} = H_{г.б} = H''_{г.o} \sin\gamma_1$	—
		(10) Значения $H_{г.o}$ определяют по формулам для схем 1, 2, 3, 9, 13, 14 (11) Значения $H'_{г.o}$ и $H''_{г.o}$ определяют по формулам для схем 4, 5, 10		
21	(9) Сальниковый или П-образный компенсатор 	(12) Неподвижная опора расположена по биссектрисе угла γ: $\gamma_1 = \frac{180-\gamma}{2}$; $H_{г.ox} = H_{г.o} \cos\gamma_1 \pm P_y \sin\gamma_1$; $H_{г.oy} = H_{г.б} = (H'_{г.o} + H''_{г.o}) \times \sin\gamma_1 + P_y \cos\gamma_1$	$H_{г.ox} = H'_{г.o} \cos\gamma_1$; $H_{г.oy} = H_{г.б} = H'_{г.o} \sin\gamma_1$; $H_{г.ox} = H''_{г.o} \cos\gamma_1 \pm P_y \sin\gamma_1$; $H_{г.oy} = H_{г.б} = H''_{г.o} \sin\gamma_1 + P_y \cos\gamma_1$	—
		(13) Значения $H_{г.o}$ определяют по формуле для схем 15, 16, 7 (14) Значения $H'_{г.o}$ и $H''_{г.o}$ определяют по формулам для схем 4, 5, 10, 19		
22	(9) Сальниковый или П-образный компенсатор 	(15) Две неподвижные опоры расположены на каждом трубопроводе перпендикулярно оси трубы: $H'_{г.o}$, $H''_{г.o}$ (16) определяют по формулам для схем 4, 5, 10		

Notes: 1. With several calculation formulas for one circuit (for example, circuit 13) value determination of horizontal loads on fixed support is produced by all given formulas, and as calculated they accept large of the obtained loads.

2. For piping diagrams with catch on designed section of pipeline as calculated horizontal load on fixed support, accept large of loads, obtained with design of circuits with open and closed catch.

3. During compilation of calculation formulas, it is considered that U-shaped compensators were carried out with bracing to value, indicated in chapter 10, and sections of pipelines with auto/self-compensation were carried out without preliminary bracing.

4. Difference in calculation formulas for $t < 250^{\circ}C$ and $t > 250^{\circ}C$ (for example, circuit 15) is explained account of phenomenon of relaxation at temperature of wall of tube more than $250^{\circ}C$ (see Chapter 10).

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5 OF 6
AD A066414



Key: (1). No. circuits. (2). Circuit of the calculated section of pipeline. (3). Calculation formulas. (4). for circuits without catches or with the open catches. (5). with closed catches. (6). the radiation circuits of thermal grid/networks. (7). circular circuit of thermal grid/networks with $D_1 \geqslant D_2$. (8). Fixed support is arrange/located on the bisector of angle γ. (9). Gasket or U-shaped compensator. (10). Values $H_{r.o}$ are determined from formulas for circuits. (11). Values $H'_{r.o}$ and $H''_{r.o}$ are determined from formulas for circuits. (12). Fixed support is arrange/located on the bisector of angle γ. (13). Values $H_{r.o}$ are determined from formula for circuits. (14). Values $H'_{r.o}$ and $H''_{r.o}$ are determined from formulas for circuits. (15). Two Statospores are arrange/located on each Pipeline perpendicular to the axle/axis of tube. (16). they determine from formulas for circuits.

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Page 238.

Table 11.4. Horizontal loads in ton-force on fixed supports from one pipeline of the water thermal grid/networks $P_{раб}$ = 16 kg/cm^2, t = 150°C with above-grade packing and the specific weight of basic insulating layer $\gamma_{из}$ = 300 kg/m^3.

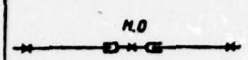
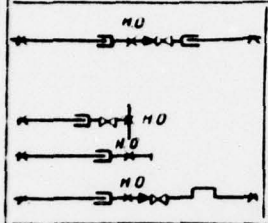
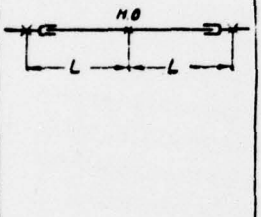
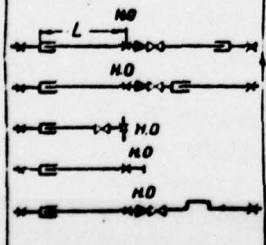
(1) Схема расчетного участка трубопровода	(2) Расчетные формулы для $H_{г.о}$ или $H_{г.б}$	(3) L в м / (5) Тип опор	(4) Нагрузки при условном проходе D_y в мм														
			100	125	150	200	250	300	350	400	450	500	600	700	800	900	1000
НО	$0,3\,P_c$	—	0,3	0,36	0,6	1,2	1,5	1,9	2,2	2,5	2,8	3,3	3,9	4,5	5,1	5,8	6,4
НО НО НО НО	$P_c + P_{раб} \times F_{с.н}$	—	2,4	3,3	5	10	13	19	24	30	37	45	62	79	100	124	150
НО L L	$0,3\,(P_c + iqL)$	L	70	70	80	80	100	100	120	140	140	140	160	160	160	160	160
		(6) Катковые	—	—	—	1,5	2	2,6	3,1	3,7	4,2	5	6,5	7,7	9	10,7	13
		(7) Скользящие	0,6	0,7	1,1	2	3	3,8	5	6	6,9	8,3	12	15	17	20	25
		L	50	50	60	60	80	80	100	110	110	110	130	130	130	130	130
		(4) Катковые	—	—	—	1,4	1,9	2,4	2,9	3,4	3,9	4,7	6	7,1	8,3	9,7	12
		(5) Скользящие	0,5	0,6	1	1,8	2,7	3,4	4,5	5,3	6,1	7,2	11	13	15	18	22
		L	30	30	40	40	60	60	80	80	80	80	100	100	100	100	100
		(6) Катковые	—	—	—	1,3	1,8	2,3	2,8	3,2	3,6	4,3	5,6	5,5	7,6	8,8	11
		(7) Скользящие	0,4	0,5	0,9	1,6	2,3	3	4	4,5	5,2	6,1	8,7	11	13	15	18
L НО НО НО НО НО	$P_c + iqL + P_{раб} \times F_{с.н}$	L	70	70	80	80	100	100	120	140	140	140	160	160	160	160	160
		(6) Катковые	—	—	—	11	15	21	27	35	42	51	71	90	113	141	170
		(7) Скользящие	3,3	4,5	6,7	13	18	25	34	42	52	61	88	111	140	173	209
		L	50	50	60	60	80	80	100	110	110	110	130	130	130	130	130
		(4) Катковые	—	—	—	11	15	20	27	34	41	49	69	88	112	140	166
		(5) Скользящие	3,1	4,2	6,3	13	17	24	32	40	49	58	82	105	132	164	198
		L	30	30	40	40	60	60	80	80	80	80	100	100	100	100	100
		(6) Катковые	—	—	—	11	14	20	26	33	40	48	67	85	108	134	163
		(7) Скользящие	2,8	3,9	6	12	16	22	31	37	46	54	78	99	125	155	187
НО L	$0,3\,P_c + iqL$	L	70	70	80	80	100	100	120	140	140	140	160	160	160	160	160
		(6) Катковые	—	—	—	2,1	3,1	4	5,3	6,4	7,5	8,8	13	16	18	22	27
		(7) Скользящие	1,3	1,6	2,3	3,9	6,3	8,1	11,4	14,3	17,6	20	30	37	45	54	66
		L	50	50	60	60	80	80	100	110	110	110	130	130	130	130	130
		(4) Катковые	—	—	—	1,8	2,8	3,6	4,8	5,6	6,5	7,6	12	14	16	19	23
		(5) Скользящие	1	1,2	1,9	3,2	5,4	6,9	10	12,3	14,6	17	25	31	37	45	55
		L	30	30	40	40	60	60	80	80	80	80	100	100	100	100	100
		(6) Катковые	—	—	—	1,6	2,5	3,2	4,3	4,7	5,5	6,5	9,2	12	13	16	20
		(7) Скользящие	0,7	0,9	1,5	2,5	4,4	5,6	8,4	9,2	11,6	13	20	25	30	36	44

Note. For circuits with catches, horizontal axial load on support is determined with closed catch and the supply of heat carrier from left side.

Key: (1). Circuit of the calculated section of pipeline. (2). Calculation formulas for $H_{r,o}$ or $H_{r,\delta}$. (3). L in m. (4). Loads with internal diameter D_y in mm. (5). Type of supports. (6). Roller. (7) Slipping.

Page 239.

Table 11.5. Horizontal loads in ton-force on fixed supports from one steam line $P_{раб}$ = 13 kg/cm^2, t = 300°C with above-grade packing and the specific weight of basic insulating layer of $\gamma_{из}$ = 300 kg/m^3.

(1) Схема расчетного участка трубопровода	(2) Расчетные формулы для $H_{т.о}$ или $H_{т.б}$	L в м / (3) Тип опор	(4) Нагрузки при условном проходе D_y в мм														
			100	125	150	200	250	300	350	400	450	500	600	700	800	900	1000
	$0{,}3\,P_c$	—	0,33	0,33	0,5	1	1,3	1,5	1,7	2	2,3	2,7	3,2	3,7	4,1	4,7	5,2
	$P_c + P_{раб} F_{с.н}$	—	2,1	2,8	4	8	12	15	20	24	30	37	50	64	82	101	120
	$0{,}3\,(P_c + qL)$	L	50	50	60	60	60	60	60	80	80	80	80	80	80	80	80
		(5) Катковые	—	—	—	1,2	1,6	1,8	2,1	2,5	2,9	3,3	3,9	4,7	5,1	5,9	6,6
		(6) Скользящие	0,6	0,63	1	1,6	2	2,4	2,9	3,4	4	4,4	5,4	6,2	7,1	8,2	9,1
		L	40	40	45	45	45	45	45	60	60	60	60	60	60	60	60
		(5) Катковые	—	—	—	1,2	1,5	1,8	2	2,3	2,8	3,1	3,7	4,4	4,9	5,6	6,2
		(6) Скользящие	0,52	0,57	0,8	1,5	1,9	2,2	2,6	3	3,6	4	4,8	5,6	6,4	7,3	8,2
		L	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40
		(5) Катковые	—	—	—	1,1	1,5	1,7	1,9	2,2	2,6	3	3,5	4,2	4,6	5,3	5,9
		(6) Скользящие	0,48	0,51	0,7	1,3	1,7	1,9	2,3	2,7	3,2	3,6	4,3	5	5,6	6,4	7,2
	$P_c + qL + F_{раб} P_{с.н}$	L	50	50	60	60	60	60	60	80	80	80	80	80	80	80	80
		(5) Катковые	—	—	—	8,7	13	16	21	25	32	39	53	67	83	105	124
		(6) Скользящие	3,1	3,8	5,5	10	14	18	24	28	35	43	58	72	92	113	133
		L	40	40	45	45	45	45	45	60	60	60	60	60	60	60	60
		(5) Катковые	—	—	—	8,5	13	16	21	25	31	38	52	66	84	104	123
		(6) Скользящие	2,8	3,6	5,1	9,7	14	18	23	27	34	41	56	70	89	110	130
		L	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40
		(5) Катковые	—	—	—	8,4	12	16	21	26	31	38	52	65	83	103	122
		(6) Скользящие	2,6	3,4	4,7	9	13	17	22	26	33	40	54	68	87	107	126

Page 240.

Tables 11.5. Continued.

(1) Схема расчетного участка трубопровода	(2) Расчетные формулы для $H_{г.о}$ или $H_{г.б}$	(3) L в мм / Тип опор	(4) Нагрузки при условном проходе D_y в мм													
			100	125	150	200	250	300	350	400	450	500	600	700	800	900	1000
	$0,3\ P_c + + lqL$	L	50	50	60	60	60	60	60	80	80	80	80	80	80	80	80
		(5) Катковые	—	—	—	1,7	2,2	2,5	3	3,5	4,1	4,6	5,7	6,4	7,4	8,5	10
		(6) Скользящие	1,11	1,3	2	3,1	3,8	4,5	5,4	6,6	7,6	8,4	11	12	14	16	19
		L	40	40	45	45	45	45	45	60	60	60	60	60	60	60	60
		(5) Катковые	—	—	—	1,5	2	2,3	2,7	3,2	3,7	4,1	5	5,8	6,6	7,6	8,5
		(6) Скользящие	1	1,1	1,6	2,6	3,2	3,7	4,5	5,4	6,3	7	8,6	10	12	13	15
		L	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40
		(5) Катковые	—	—	—	1,4	1,8	2	2,4	2,7	3,2	3,6	4,3	5,1	5,8	6,6	7,1
		(6) Скользящие	0,82	0,93	1,2	2,1	2,6	3	3,6	4,3	5	5,5	6,6	7,8	9,1	11	12

Note. For circuits with catches, horizontal axial load on support is determined with the closed catch also of the supplies of heat carrier from left side.

Key: (1). Circuit of the calculated section of pipeline. (2). Calculation formulas for $H_{г.о}$ or $H_{г.б}$. (3). L in mm / the type of supports. (4). Loads with internal diameter D_y in mm. (5). Roller. (6). Sliding.

In the latter case the calculation is performed without taking into account of the counteraction of section, arrange/located along another side of reinforcement, on the basis of the condition of the possibility of the supply of heat carrier from one or on the other hand.

Counter action of the section, arrange/located along another side of reinforcement, one should consider only for the ring circuits when can occur the warming up of the section of pipeline along one side of reinforcement and is simultaneous cooling section along another side, i.e., when forces affecting the fixed support of both sections, are totaled.

Side horizontal loads on fixed saddles from branches are defined along the axis of the pipeline of branch as for end support.

For the most widely used cases of piping diagrams, are comprised calculation formulas for determining the horizontal loads, which effect on fixed saddles (tables 11.3).

For some circuits table 11.4-11.7 gives values of horizontal loads on fixed supports for the above-grade packing of thermal grid/networks with the parameters of the heat carriers: pairs $P_{раб}$ = 13 kg/cm², t = 300°C and water $P_{раб}$ = 16 kg/cm² and t = 150°C.

Example I. To determine horizontal axial load affectig fixed saddle $D_н$ = 630 x 7 mm. The circuit of calculated section is given on Fig. 11.6. Heat carrier is water $P_{раб}$ = 16 kg/cm². Packing in impassable channel. Supports sliding. Weight 1 m of pipeline with water and insulation construction q = 523 kg/m. Angle γ = 150°C. Fixed support is arrange/located on the bisector of angle.

Solution. Calculated formulas are accepted according to circuit 20 tables.

11.3. Value $H'_{г.о}$ and $H''_{г.о}$ is determined from formula for circuit 5:

$$H'_{г.о} = H''_{г.о} = P_c + fqL + P_{раб} F_{с.н} m_c;$$

P_c = 13 ton-force on curve/graph Fig. of 11.1; fqL = 523·0.3·100=15,700 kgf, or approximately 15 ton-force; $P_{в.д} - P_{раб} F_{с.н}$ = 48.6 ton-force on curve/graph Fig. 11.3.

Thus, $H'_{r.o} = H''_{r.o}$ = 13+49+16+78 ton-force. We determine value $H_{r.o}$ by formula for circuit 2

$$H_{r.o} = 0.3\,(P_c + fqL) = 0.3\,(13+16) = 8.7 \text{ t-s}.$$

We determine force component which acts along the axle/axis of stationary support $(H_{r.ox})$ and is perpendicular to it $(H_{r.oy})$:

$$H_{r.ox} = H_{r.o}\cos\gamma_1 = 8.7\cos 15^\circ = 8.4 \text{ t-s};$$
$$H_{r.oy} = (H'_{r.o} + H''_{r.o})\sin\gamma_1 = (78+78)\sin 15^\circ = 41 \text{ t-s}.$$

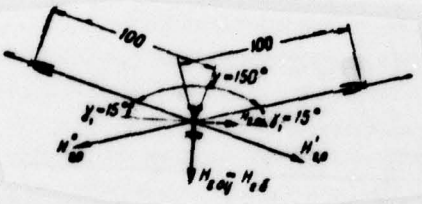
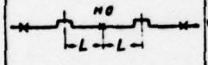
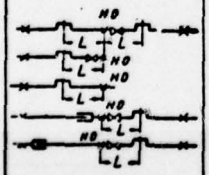


Fig. 11.6. Circuit of calculated section.

Page 241.

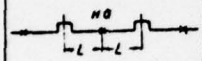
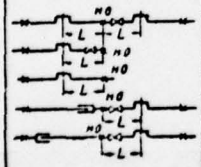
Tables 11.6. Horizontal loads in ton-force on fixed supports from one pipeline of the water thermal grid/networks $P_{раб}$ = 16 kg/cm²; t = 150°C with above-grade packing and the specific weight of basic insulating layer of $\gamma_{из}$ = 300 kg/m³.

(1) Схема расчетного участка трубопровода	(2) Расчетные нагрузки $0.3(P_{р.в}+P_{р.в})$ и $H_{р.в}$	(3) L в м / (5) Тип опор	(4) Нагрузки при условном проходе D_y в мм																				
			32	40	50	70	80	100	125	150	175	200	250	300	350	400	450	500	600	700	800	900	1000
	•	L	25	30	30	35	40	40	45	50	50	60	60	60	70	80	80	90	100	100	100	100	100
		Катковые (4)	–	–	–	–	–	–	–	–	–	0,4	0,6	0,8	1,1	1,1	1,3	1,6	2,4	3	3,6	4,8	6
		Скользящие (7)	0,1	0,1	0,1	0,1	0,1	0,2	0,3	0,4	0,5	0,8	1,1	1,5	2,2	2,5	2,9	3,7	5,6	6,8	7,5	11	13
		L	20	25	25	30	30	30	35	40	40	50	50	60	55	65	65	70	80	80	80	80	80
	$0.3(P_{р.в}+$ $+\gamma_{из}L)$	Катковые (5)	–	–	–	–	–	–	–	–	–	0,4	0,5	0,8	1	1,2	1,4	1,4	2,2	2,7	3,6	4,3	5,4
		Скользящие (8)	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,4	0,5	0,7	1,0	1,4	1,9	2,1	2,5	3	4,7	5,8	7,4	9,2	11
		L	15	20	20	20	20	20	25	30	30	40	40	40	40	50	50	50	60	60	60	60	60
		Катковые (6)	–	–	–	–	–	–	–	–	–	0,4	0,5	0,8	1	1	1,1	1,3	2	2,4	3,2	4	5,1
		Скользящие (9)	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,3	0,4	0,7	0,9	1,2	1,6	1,8	2,1	2,5	3,9	4,8	6,2	7,7	9,5
	$P_{р.в}+$ $+\gamma_{из}L$	L	25	30	30	35	40	40	45	50	50	60	60	60	70	80	80	90	100	100	100	100	100
		Катковые (10)	–	–	–	–	–	–	–	–	–	1,3	1,9	2,6	3,6	3,7	4,4	5,3	8	9,6	13	16	20
		Скользящие (13)	0,2	0,2	0,3	0,4	0,5	0,7	0,9	1,4	1,8	2,7	3,8	5,1	7,3	8,2	9,7	12	19	23	25	36	41
		L	20	25	25	30	30	30	35	40	40	50	50	50	55	65	65	70	80	80	80	80	80
		Катковые (11)	–	–	–	–	–	–	–	–	–	1,3	1,8	2,5	3,5	3,4	4	4,7	7,2	8,8	12	14	18
		Скользящие (14)	0,1	0,2	0,2	0,4	0,4	0,6	0,8	1,2	1,6	2,4	3,4	4,6	6,3	7,1	8,3	10	16	19	25	31	38
		L	15	20	20	20	20	20	25	30	30	40	40	40	40	50	50	50	60	60	60	60	60
		Катковые (12)	–	–	–	–	–	–	–	–	–	1,2	1,8	2,5	3,4	3,2	3,8	4,3	6,6	8	11	13	17
		Скользящие (15)	0,1	0,2	0,2	0,3	0,3	0,5	0,7	1	1,4	2,1	3,1	4,2	5,5	6	7,1	8,2	13	16	21	26	32

Note. For circuits with catches, axial load on support is determined with closed catch and the supply of heat carrier from right side.

Key: (1). Circuit of the calculated section of pipeline. (2). Calculation formulas for $H_{r.o}$ and $H_{r.6}$. (3). L in m. (4). Loads with internal diameter D_y in mm. (5). Type of supports. (6). Roller. (7). Sliding.

Tables 11.7. Horizontal loads in ton-force on fixed supports from one steam line $P_{раб}$ = 13 kg/cm², t = 300° C with above-grade packing and the specific weight of basic insulating layer of $\gamma_{из}$ = 300 kg/m³.

(1) Схема расчетного участка трубопровода	(2) Расчетные формулы для $H_{г.о}$ и $H_{г.б}$	L в м (3) / (5) Тип опор	Нагрузки при условном проходе D_y в мм (4)																						
			25	32	40	50	70	80	100	125	150	175	200	250	300	350	400	450	500	600	700	800	900	1000
	0,3 ($P_н$+|q|L)	L	25	25	30	30	35	40	40	45	45	50	50	50	60	60	70	70	80	80	80	80	80	80
		Катковые (5)	–	–	–	–	~	–	–	–	–	–	0,3	0,5	0,6	0,8	0,8	0,9	1	1,4	1,6	2,1	2,6	3,2
		Скользящие (5)	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,3	0,4	0,5	0,7	0,9	1,2	1,5	1,6	1,8	2,2	2,9	3,2	4,1	4,9	5,8
		L	20	20	25	25	30	30	30	35	35	40	40	40	50	50	55	55	65	65	65	65	65	65
		Катковые (6)	–	–	–	–	~	–	–	–	–	–	0,3	0,4	0,6	0,8	0,7	0,9	1	1,3	1,5	2	2,5	3,1
		Скользящие (6)	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,3	0,3	0,4	0,6	0,8	1,1	1,4	1,3	1,6	1,9	2,5	2,9	3,6	4,4	5,3
		L	15	15	20	20	20	20	20	25	25	30	30	30	40	40	40	40	50	50	50	50	50	50
		Катковые (7)	–	–	–	–	~	–	–	–	–	–	0,3	0,4	0,6	0,8	0,7	0,8	0,9	1,3	1,5	2	2,5	3,1
		Скользящие (7)	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,3	0,4	0,4	0,5	0,7	1	1,3	1,1	1,3	1,6	2,2	2,5	3,2	3,9	4,7
	$P_н$+|q|L	L	25	25	30	30	35	40	40	45	45	50	50	50	60	60	70	70	80	80	80	80	80	80
		Катковые (6)	–	–	–	–	~	–	–	–	–	–	1	1,5	2	2,7	2,5	2,9	3,4	4,7	5,4	7	8,7	11
		Скользящие (6)	0,2	0,2	0,2	0,3	0,4	0,6	0,8	1	1,3	1,7	2,2	2,9	4	5,1	5,3	6	7,2	10	11	14	16	19
		L	20	20	25	25	30	30	30	35	35	40	40	40	50	50	55	55	65	65	65	65	65	65
		Катковые (6)	–	–	–	–	~	–	–	–	–	–	1	1,4	2	2,6	2,3	2,8	3,2	4,5	5,1	6,7	8,3	10
		Скользящие (6)	0,1	0,2	0,2	0,3	0,4	0,5	0,6	0,9	1,1	1,4	1,9	2,5	3,6	4,6	4,1	5,3	6,3	8,4	9,5	12	15	18
		L	15	15	20	20	20	20	20	25	25	30	30	30	40	40	40	40	50	50	50	50	50	50
		Катковые (7)	–	–	–	–	~	–	–	–	–	–	1	1,3	1,9	2,6	2,3	2,6	2,9	4,1	5	6,6	8,3	10
		Скользящие (7)	0,1	0,1	0,2	0,2	0,3	0,4	0,5	0,7	0,9	1,2	1,6	2,2	3,3	4,2	4,6	4,4	5,4	7,1	8,4	11	13	16

Note. For circuits with catches, horizontal axial load on support is determined with closed catch and to the supply of heat carrier from it is right side.

Key: (1). Circuit of the calculated section of pipeline. (2). Calculation formulas for $H_{r.o}$ and $H_{r.б}$. (3). L in m. (4). Loads with internal diameter D_y in mm. (5). Type of supports. (6). Roller. (7). Sliding.

Section III.

LAYING OF THERMAL NETWORKS

Chapter 12.

OVERALL QUESTIONS OF PACKING.

12.1. General considerations.

For thermal grid/networks are applied the following basic methods of packing:

underground packing is channel-free; in impassable channels; in semiaccess channels, in tunnels (passage

channels); in common/general/total collector/receptacles together with other communications; in the technical corridors of basements and the technical undergrounds of buildings;

above-grade packing - on piers with span structure or on the separate high supports (masts); on low supports (columns, ties, etc.); on walls within or outside buildings.

For the habitable city districs and populated places, on the basis of architectural considerations, is applied underground applying of thermal grid/networks.

Above-grade packing in residential areas is applied as exception/elimination under extra-heavy ground conditions (areas of the ever-frozen soils, which are squandered with thawing, the vacant, swampy sections of route, etc.

Table 12.1 and 12.2 gives exemplary/approximate joinings during the arrangement/position of two-funnelled water thermal grid/networks in the impassable standardized channels of a standard series of ~~artificial satellite-01-04~~ IS-01-04 GOSSTROY of the USSR

This type of packing can be applied under any ground conditions with device in the zone of ground water of the incidental filtering drainage or backing hydraulic sealing.

Channel-free packing applied for a heat carrier with the temperature not more than 180°C and only at good ground conditions.

Is forbidden the application/use of channel-free packing in seismic areas with 7 points and it is above, in settled and ever-frozen soils, and also in areas of mine workings.

The arrangement/position of two-funnelled water thermal grid/networks in cross section with channel-free packing in shells of autoclave cellular concrete see in Chapter 15.

Packing in semiaccess channels is applied in cities on the individual sections of route in essence during the intersection of areas and passages with intense motion or with the improved bridge. According to operating conditions, semiaccess channels are equated to impassable. The service

personnel is allow/assumed into semiaccess channels only when pipeline does not work.

In residential areas in passage channel-tunnels, thermal grid/networks, as a rule, are not laid. The joint packing of thermal grid/networks with other utility networks in common/general/total passage tunnel- collector/receptacles finds a use in large cities during the reconstruction of those who exist and building of new main-line passages (Fig. 12.1), also, in certain cases - for the large residential areas of new building.

Besides thermal grid/networks in collector/receptacles, lay the grid/networks of water pipe, communication cables, power and illuminating cables by stress to 35 kV and downpour channelization.

for distributive water thermal grid/networks by diameter 300 mm and is allow/assumed below the packing in technical corridors or technical undergrounds of habitable and public buildings, if in this case does not increase the length of routes and building thermal grid/networks it is realize/accomplished simultaneously with building of buildings.

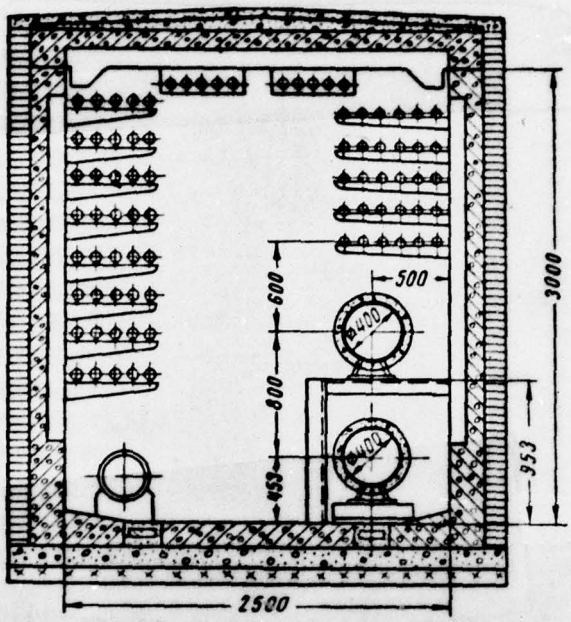


Fig. 12.1. Joint packing of thermal grid/networks with other urban utility networks in common/general/total collector/receptacles.

Page 244.

Packing laying under the existing buildings is allow/assumed with the condition of isolation/liberation in the basement of the building of the special technical corridor with independent outcrops.

In the territory of industrial enterprises, is allow/assumed the packing of thermal grid/networks outside or within buildings, if in this case are not disturbed the conditions safety and of norm technique of illumination and is not required strengthening the structures of the latter.

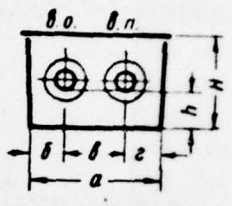
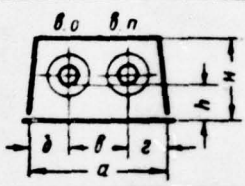
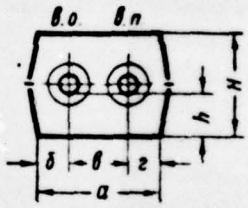
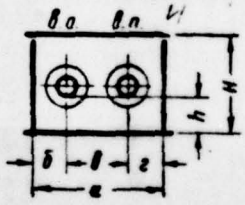
To above-grade packing is loosened advantage, if by enterprise is accepted the above-grade packing of technological pipelines and there is the technical capability of the joint packing of all pipelines by common/general/total piers or high supports.

Above-grade packing is recommended the applying of in poor hydrogeological conditions (high level of ground water, settled earth, and the like).

For steam lines with pressure pair P $\geq$ 22 kgf/cm^2, as a rule, is applied only Above-ground packing on piers or high supports.

The underground packing of thermal grid/networks in industrial enterprises is applied in good hydro-geological conditions and in a small quantity of laid tubes (2-4). On the head section of the route where a quantity of pipelines and their diameters grow/rise, can prove to be advisable building passage channel (tunnel).

Table 12.1. Arrangement/position of two-funnelled water thermal grid/networks in inpassable unicellular channels.

(1) Трубы D_y в мм	(2) Марка канала	(3) Одноячейковый канал, размеры в мм						(4) Эскиз
		а	б	в	г	h	H	
25	КЛ60-45	600	175	250	175	196	460	
32	КЛ60-45	600	175	250	175	196	460	
40	КЛ60-45	600	150	300	150	196	460	
50	КЛ60-45	600	150	300	150	196	460	
70	КЛ60-45	600	150	300	150	196	460	
80	КЛ60-45	600	150	300	150	196	460	
100	КЛ90-45	900	225	450	225	196	460	
125	КЛ90-45	900	225	450	225	196	460	
150	КЛ90-45	900	225	450	225	196	460	
175[1]	КЛ120-60	1200	340	600	340	195	590	
200[1]	КЛ120-60	1200	340	600	340	196	590	
250[1]	КЛ120-60	1200	340	600	340	196	590	
175	КЛс150-90	1500	450	600	450	196	830	
200	КЛс150-90	1500	450	600	450	196	830	
250	КЛс150-90	1500	450	600	450	196	830	
300	КЛс150-90	1500	400	700	400	246	830	
350	КЛс150-90	1500	400	700	400	246	830	
400	КС210-90	2100	550	1000	550	246	900	
500	КС210-90	2100	550	1000	550	246	900	

Key: (1). Tubes D_y in mm. (2). the mark/brand of channel. (3). Unicellular channel, size/dimensions in mm. (4). Draft/drawing.

FOOTNOTE 1. Only for unsettled soils. ENDFOOTNOTE.

Page 245.

Is not allow/assumed the packing of thermal grid/networks in impassable channels or the tunnels of enterprises together with oxygen lines, with the pipelines of the compressed air by the pressure above 16 kgf/cm², with the pipelines of the inflammable and toxic liquids, or with power and illuminating cables and the pipelines of fecal and downpour channelization.

On the vacant territory of industrial areas, cities it is settlement (breakage between enterprises and habitable arrays, areas, which are not subject to building-up on ground conditions, area relief and the like), as a rule, apply above-grade packing in low supports (columns or ties). High supports and piers in this case are utilized with the

large number of intersections with highways and with railroads.

With a small quantity of railway lines the intersection of the latter with heating mains they permit without the application/use of special high supports (Fig. 12.2).

In areas of mine workings, is applied the packing of thermal grid/networks only in low supports.

Table 12.2. Arrangement/position of two-funnelled water thermal grid/networks in impassable two-cellular channels.

(1) Диаметр трубопровода D_y в мм	(2) Марка канала	(3) Двухячейковый канал, размеры в мм						(4) Эскиз
		а	*б*	*в*	*г*	*h*	*H*	
175	2КЛс60-60	600	260	860	100	196	590	
200	2КЛс60-60	600	260	860	100	196	590	
250	2КЛс60-60	600	260	860	100	196	590	
400	2КЛс90-90	900	260	1160	100	246	910	
500	2КЛс90-90	900	260	1160	100	246	910	
600	2КЛс120-120	1200	300	1500	100	246	1170	
700	2КЛс120-120	1200	300	1500	100	246	1170	
600	2КС120-120	1270	160	1430	—	246	1200	
700	2КС120-120	1270	160	1430	—	246	1200	
800	2КС120-120	1270	160	1430	—	246	1200	
900	2КС150-150	1570	160	1730	—	296	1500	
1000	2КС150-150	1570	160	1730	—	296	1500	
1200	2КС180-180	1800	160	1960	—	301	1800	

Key: (1). Diameter of pipeline D_y in mm. (2). Mark/brand of channel. (3). Two-cellular channel, size/dimensions in mm. (4). Draft/drawing.

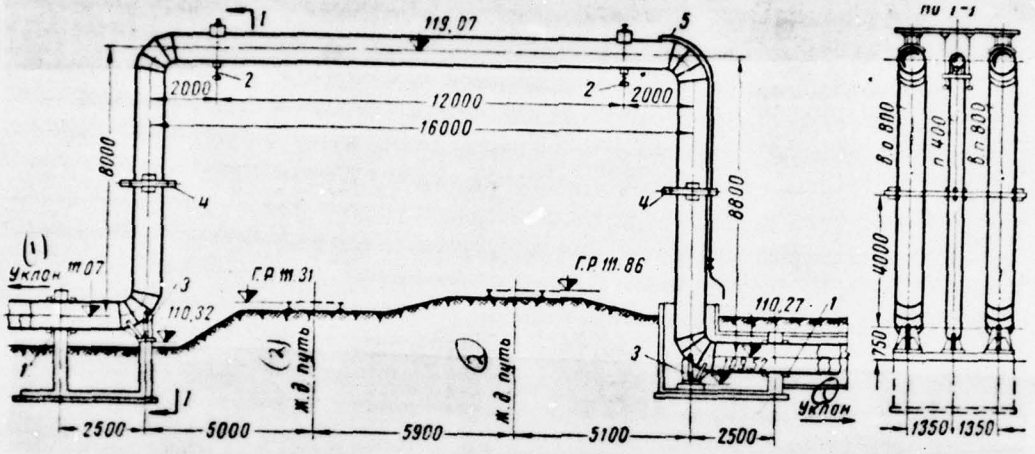


Fig. 12.2. Intersection of railway lines with heating mains without the application/use of special high supports. 1 - fixed supports; 2 - suspension spring cushions; 3 - step bearings; 4 - the frame of rigidity; 5 - tube for air exhaust (are insulated together with the basic tubes); g.r. - the head of rails; v.p. - water line feeding; v.o. - water line is reverse/inverse; p - steam line.

Key: (1). Gradient/draft. (2). RR [zh.d.] / way.

The method of packing in ever-frozen soils depends in essence on the character of soils and effect on them of the heat releases of the pipelines of thermal grid/networks. If at the depth of thawing with the underground packing of thermal grid/networks lie unsettled soils (rock, skeletal/skeleton, etc.), are accepted the same methods of packing that and of outside areas permafrost.

If the route of thermal grid/networks passes along the territory of the building-up where all buildings are constructed taking into account the preservation/retention/maintaining of the permafrost, then is applied above-grade packing in pier, low or high supports, on the garrets of buildings, on the aerated undergrounds at the height which does not disturb the permafrost.

As an exception, is applied the underground method of packing in impassable channels or in passage tunnels. In this case impassable channels and tunnels must be provided by ventilation with the supply of cold air in the quantity, which eliminates the thawing of soil or which reduces this thawing to the minimum.

The sinking of channels and tunnels is accepted

minimum, and where this is possible according to local conditions, the overlap of channels protrudes above the earth's surface.

Entrances into areas of ever-frozen soils in all cases are fulfilled above-grade. With underground tubing on branch to buildings at a distance 6-10 m of input/introduction, they are derive/concluded from channels to the mark of the sex/floor of the first deck and are laid on this section on low supports.

12.2. Route and the longitudinal section of thermal grid/networks.

The route of thermal grid/networks is selected in parallel to the axle/axis of passage or line of building-up in accordance with the requirements for SNIP II-K.1-62, SNIP II-K.3-62; SNIP II-K.2-62; SNIP II-M.1-62.

One should not lay thermal grid/networks in one passage in parallel with tramroads and the suction cables of direct current, or in the band of alienation in parallel to

railroad and in forbidden zone of industrial enterprises (SNIP II-6 10-62).

One should also avoid intersections and approaches of thermal grid/network with the rail tracks of the electrified (on direct current) transport, and also with other sources of stray currents, if this is not led to an essential increase in the length of route.

Within the limits of passages, the route of thermal grid/networks is marked out, as a rule, under the bands of green cultivations, under sidewalks, and with the impossibility of this arrangement/position - under transient part in extreme bands.

With the constriction of passages and saturation by their large quantity of underground communications the route of thermal grid/networks is marked out as exception/elimination on the territory of quarters.

When selecting of the route of thermal grid/networks on the territory of industrial enterprises, is considered the possibility of the joint packing of thermal grid/networks with different technological communications in overall structures.

On the vacant territory the route of thermal grid/networks is selected as far as possible along roads, avoiding intersection it flowed, ravines and swampy places.

On the floodland territory of rivers, one should the route of thermal grid/networks accept only in the presence of the artificial constructions which can be used for the packing of thermal grid/networks. The independent packing of thermal grid/networks on floodland territory, as a rule, is not applied.

Table 12.3. Minimum distances in plan/layout also with respect to vertical line in world/light from the constructions of thermal grid/networks to utility networks and other constructions.

(1) Наименование расстояний	Минимальные расстояния в свету в м (2)	
	в плане (3)	по вертикали (4)
(5) При подземной прокладке тепловых сетей		
(6) До ближайшего трамвайного рельса	2	—
(7) До ближайшего рельса электрифицированной железной дороги	10	—
(8) До оси ближайшего железнодорожного пути (но не менее чем на глубину траншеи тепловой сети до подошвы насыпи пути)	4	—
(9) До стрелок, крестовин и мест присоединения к рельсам электрифицированных железных дорог (при их пересечении):		
(10) трамвайные и железнодорожные пути	3	—
(11) электрифицированные железные дороги	10	—
(12) До подошвы рельса трамвайных и железных дорог	—	1
(13) До бордюрного камня автомобильной дороги	1,5	—
(14) До наружной бровки кювета или подошвы насыпи автомобильной дороги	1	—
(15) До дорожного покрытия автомобильной дороги:		
(16) для каналов, тоннелей и конструкций бесканальной прокладки тепловых сетей	—	0,5
(17) для камер	—	0,3
(18) При отсутствии дорожного покрытия: для каналов и тоннелей и конструкций бесканальной прокладки тепловых сетей	—	0,7
(19) для камер	—	0,5
(20) До обреза фундаментов зданий и сооружений:		
(21) при прокладке на уровне или выше оснований	2	—
(22) то же, в вечномерзлых грунтах	6	—
(23) при прокладке ниже оснований фундаментов в зависимости от глубины заложения тепловых сетей и фундаментов с учетом естественного откоса грунта, но не менее	5	—
(24) то же, в вечномерзлых грунтах	10	—
(25) До подошвы фундаментов зданий и сооружений (от дна канала или тоннеля тепловой сети)	—	0,5
(26) До обреза фундаментов опор технологических трубопроводов или мачт наружного освещения и сети связи:		
(27) при прокладке на уровне или выше оснований	1	—
(28) то же, для опор путепроводов	2	—
(29) то же, для столбов наружного освещения или сети связи	1	—
(30) До кабелей связи	2	0,5
(31) До бронированного телефонного кабеля	1	0,5
(32) До бронированного телефонного кабеля в трубах или до блока телефонной канализации	1	0,15
(33) До электрокабелей напряжением не свыше 35 кв	2	0,5
(34) то же, напряжением до 220 кв	2	1
(35) До газопровода давлением не свыше 6 кГ/см²	2	0,2
(36) то же, давлением 6—12 кГ/см²	4	0,2
(37) До водопровода (но не менее разницы в глубине заложения)	1,5	0,2
(38) До водостоков	1	0,2
(39) До канализации	1	0,2
(40) То же, для открытых систем тепловых сетей и отдельных трубопроводов горячего водоснабжения при прокладке на уровне или выше канализации при диаметре тепловых сетей:		
(41) меньше 200 мм	1,5	0,4
(42) больше 200 мм	3	0,4

Table 12.3 (continued)

(49) По канализации при прокладке ниже канализации независимо от диаметра	5	(44) Не рекомендуется
(46) По оси дерева с кроной не более 5 м в диаметре	2	—
(47) По кустарника	1	—
(48) По кладбищ, свалки, скотомогильников, для открытых систем тепловых сетей или отдельных трубопроводов горячего водоснабжения	10	—
(49) То же, при наличии на уровне прокладки тепловых сетей грунтовых вод с движением потока в сторону тепловых сетей	30	—
(50) По уборных, выгребных и помойных ям, для открытых систем тепловых сетей или отдельных трубопроводов горячего водоснабжения	7	—
(51) То же, при наличии на уровне прокладки тепловых сетей грунтовых вод с движением потока в сторону тепловых сетей	10	—
(52) При надземной прокладке тепловых сетей		
(53) По железных дорог широкой колеи:		
(54) до оси ближайшего пути	3,1	—
(55) » головки рельса	—	6,4
(56) То же, электрифицированных дорог	—	7
(57) По железных дорог узкой колеи:		
(58) до оси ближайшего пути	2,4	—
(59) » головки рельса	—	4,4
(60) По трамвайных путей:		
(60) до оси ближайшего пути	2,8	—
(61) » головки рельса	—	4,6
(62) По автомобильных дорог:		
(63) до грани бордюрного камня или внешней бровки кювета	0,5	—
(64) до одежды проезжей части	—	4,5
(65) По пешеходных дорог и проходов	—	2
(66) По поверхности земли при прокладке на низких опорах при ширине ряда труб:		
(67) до 1,5 м	—	0,35
(68) более 1,5 м	—	0,5
(69) До проводов троллейбуса (ниже тепловых сетей)	—	0,2
(70) По оси дерева с кроной не более 3 м в диаметре	2	—
(71) До проводов линий электропередач в плане при наибольшом их отклонении и по вертикали при наибольшей стреле провеса от любой части конструкций тепловых сетей, включая лестницы, площадки, ограждения и пр. при напряжении до:		
20 кв (71)	3	3
35—110 кв (72)	4	4
150 »	4,5	4,5
220 »	5	5
330 »	6	6
500 »	6,5	6,5

Notes: 1. Decrease in the norms of approach/approximation is allow/assumed only under the squeezed conditions with special substantiation and agreement with the appropriate organizations.

2. During decrease in norms of approach/approximation to edge of foundations, must be accepted measures, which eliminate possibility of destabilization of constructions.

3. Decrease in norms of approach/approximation for open thermal grid/networks and separate systems of hot water supply must be agreed with organ/controls of sanitary supervision.

Key: (1). Designation of distances. (2). Minimum clearances in m. (3). in plan/layout. (4). on vertical line. (5). With the underground packing of thermal grid/networks. (6). On the nearest tram rail. (7). To the nearest rail of the electrified railroad. (8). To the axle/axis of nearest railway line (but it is not less than at the depth of trenches of thermal grid/network of up to the bottom of the mound of way). (9). To arrow/pointers, crosses and wiring points to the rails of the electrified railroads (during their intersection). (10). tram and railway lines.

(11). the electrified railroads. (12). To the rail flange tram and railroads. (13). To border stone of highway. (14). To external edge container or the bottoms of the mound of highway. (15). To road surface of highway. (16). for the camera/chambers. (17). In the absence of road surface. (18). for channels and tunnels and the constructions of the channel-free packing of thermal grid/networks. (19). for the camera/chambers. (20). To the edge of the foundations of buildings and constructions. (21). with packing at the level or it is higher than the base/roots. (22). the same, in ever-frozen soils. (23). with packing it is lower than the base/roots of foundations depending on the depth of the laying of thermal grid/networks and foundations taking into account the slope of repose of soil, but it is not less. (24). the same, in ever-frozen soils. (25). To foundation level of buildings and constructions (from the bottom of channel or tunnel of the thermal grid/network). (26). To the edge of the foundations of the supports of technological pipelines or masts of exterior lighting and communication network. (27). with packing at the level or it is higher than the base/roots. (28). the same, for the supports of overbridges. (29). the same, for the columns of exterior lighting or communication network [1].

FOOTNOTE 1. With the packing lower than base/roots of the foundations of supports or masts of distance, they increase to the difference in the depth of laying. ENDFOOTNOTE.

(30). To communication cables. (31). To the armor plated telephone cable. (32). To the armor plated telephone pipe cable or to the block of telephone channelization. (33). Up to electric cables by stress it is not more than 35 kV. (34). The same, by stress to 220 kV. (35). To gas pipe by pressure it is not more than 6 kgf/cm^2. (36). the same, by pressure 6-12 kgf/cm^2. (37). To water pipe (but it is not less than the difference in the depth of laying). (38). To drains. (39). Before channelization. (40). The same, for the open systems of thermal grid/networks and separate pipelines of hot water supply with packing at the level or is higher than the channelization with the diameter of thermal grid/networks. (41). it is less than 200 mm. (42). it is more than 200 mm. (43). Before channelization with packing, it is lower than the channelization independent of diameter. (44). It is not recommended. (45). To the axle/axis of wood/tree with crown

it is not more than 5 m in diameter. (46). To bushes. (47). To cemeteries, dump, cattle cemeteries, for the open systems of the thermal networks or separate pipelines of hot water supply. (48). the same, when, at the level, the packing of the thermal grid/networks of ground water is present, with flow to the side of thermal grid/networks. (49). To restrooms, dredging and slop pits, for the open systems of thermal grid/networks or separate pipelines of hot water supply. (50). the same, when, at the level, the packing of the thermal grid/networks of ground water is present, with flow to the side of thermal grid/networks. (51). With the above-grade packing of thermal grid/networks. (52). To the railroads of wide gauge. (53). To the axle/axis of the nearest way. (54). to the head of rail. (55). The same, the electrified roads. (56). To the railroads of the narrow gauge. (57). to the axle/axis of the nearest way. (58). to the head of rail. (59). To tramroads. (60). to the axle/axis of the nearest way. (61). to the head of rail. (62). To highways. (63). to the face of curb stone or external edge container. (64). to the clothing of transient part. (65). To pedestrian roads and passes. (66). To the earth's surface with packing on low supports with the width of run of pipes. (67). to. (68). it is more. (69). To the wire/conductors of trolley bus

(lower than thermal grid/networks). (70). To the axle/axis of wood/tree with crown it is not more than 3 m in diameter. (71). To the wire/conductors of electric power lines in plan/layout with the greatest deviation also with respect to vertical line with the greatest deflection from any part of the constructions of thermal grid/networks, including staircases, area/site, enclosure/protections, etc. with stress of up to. (72). kV.

Page 247.

When selecting of the route of the thermal grid/networks of the intersection of the rivers of ravines, of railroads, of tramroads, highways and passages, they must be provided for at right angles or in the exceptional cases at an angle, close to straight line, but it is not less than 45°.

The route of thermal grid/networks must be design/projected taking into account possible packing in the passages of other underground communications (gas pipes, electric cables, water pipe, channelization, storm drains and so forth) with rational mutual arrangement.

The bandwidth for thermal grid/networks with underground packing is determined by the external dimensions of the units and camera/chambers. Niches can be placed above other communications. The dimensions of niches limit the approach/approximation of route to buildings.

The bandwidth with above-ground packing on piers and high supports flexible compensators can be placed above passages and railway lines. the flights of compensators in this case limit the approach/approximation of route to buildings.

Distances in plan/layout also with respect to vertical line from the constructions of thermal grid/networks to the in parallel arranged/located or intersected buildings, the constructions, the roads, and other utility networks must be in world/light not less indicated in Table 12.3.

With the underground packing of the intersection of thermal grid/networks with channelization, drains, gas pipe and communication cable, they can be fulfilled under these grid/networks or above them.

With packing above other grid/networks, is checked the need for their protection from the transmission of vertical load, with packing hearth by them provide for the devices, which prevent them from possible damages. Under the especially squeezed conditions is allow/assumed during intersection to pass the water pipe, channelization, drain and gas pipe with pressure to 6 kgf/cm^2 through channels or the camera/chamber of thermal grid/networks in cover from the steel tubes whose ends must be derived on 2 m to both sides beyond the limits of the intersected constructions.

By thermal grid/networks the intersection of electric cables, as a rule, is produced hearth by them.

The indicated in Table 12.3 norms of the approach/approximations of thermal grid/networks with underground packing to electric cables are accepted on the basis of the conditions that during intersection for all extent/elongation of approach the temperature of soil in the place of the packing of electric cable must not be raised by more than 10°C in comparison with the lowest temperature

of soil in winter period and by 15°C - in summer period.

At parallel packing the temperature of soil in the place of the packing of electric cable at any time of year must not be raised by more than 10°C for cable lines by stress to 10 kV even 5°C - for lines by stress 35-220 kV.

Is allow/assumed decrease in the norms of approach/approximation, if are not exceeded the indicated limits of an increase in the temperature of soil in comparison with the natural temperature of soil in the place of the packing of electric cable.

In the case of strengthening the heat insulation of thermal grid/networks, are not provided the necessary norms of an increase in the temperature of soil and in accordance with the "Rules of the device of electrical devices" is allow/assumed accomplishing one of the following measures: the sinking of cables to 0.5 m instead of 0.7; the application/use of cable insets of larger section/cut; cable laying under thermal grid/networks in tubes, at a distance in world/light from the constructions of thermal grid/networks is not less than on 0.5 m; in this case the

tubes must be packed so that the replacement of cables could be carried out without the need for the production of earthwork.

Page 248.

The selected direction of the route of thermal grid/networks taking into account the norms of approach/approximation to constructions and communications will be applied to the plan/layout for geodetic photography with the grid/networks of underground communications with the joining of main directions to the existing buildings and constructions.

On the route of thermal grid/networks, is constructed the longitudinal section on the basis of the project of vertical planning (organization of relief) and of the location shooting, obtained as a result of leveling route.

To the longitudinal section of heating mains besides the planning and black/ferrous marks of the earth/ground, will be applied the level of the standing of ground and surface water, mark of the sex/floors of the buildings, connected to thermal grid/networks, the marks of heads rail,

the intersected railway lines and streetcar, the existing and design/projected underground communications and other constructions, intersected by thermal grid/networks, with placing of their marks. Marks are given in absolute calculation/enumeration.

Figures 12.3 shows an example of the longitudinal section of thermal grid/network with underground packing in impassable channels.

If thermal grid/networks are design/projected with incidental filtering tubular drainage, it must be reflected in plan/layout and in the airfoil/profile of route.

The depth of the laying of thermal grid/networks with their underground packing from topographic surface in world/light is accepted not less:

(1) До верха перекрытий каналов, тоннелей и конструкции бесканальной прокладки при дорожном покрытии . . . . . 0,5 м
(2) При отсутствии дорожного покрытия . . . . 0,7 »
(3) До верха перекрытия камер и узлов в проходных тоннелях при наличии дорожного покрытия . . . . . 0,3 »
(4) При отсутствии дорожного покрытия . . . 0,5 »

Key: (1). To the top of the overlaps of channels, tunnels and construction of channel-free packing with road surface.

(2). In the absence of road surface. (3). To the top of the overlap of the camera/chambers and units in passage tunnels in the presence of road surface. (4). In the absence of road surface.

Is allow/assumed the construction of camera/chambers and units of passage tunnels in impassable places those who protrude above the earth's surface to height/altitude not less than 0.4 m.

The height/altitude of the above-grade packing of heating mains on low supports from topographic surface to the bottom of the insulation construction of pipelines must be in world/light not less than 0.5 m, sometimes is allow/assumed decrease in this distance to 0.35 m. In the sites of installation of reinforcement and equipment, must be arranged asphalt or concrete area/sites with clearance among hollow of area/site and the bottom of equipment not less than 0.5 m.

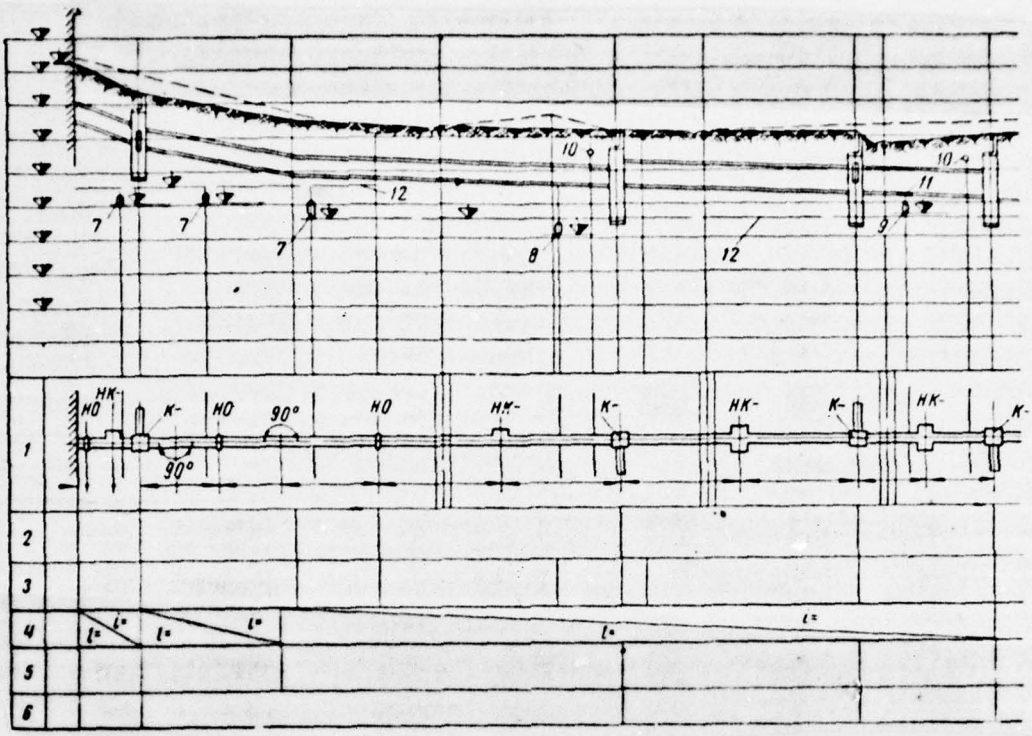


Fig. 12.3. The longitudinal section of thermal grid/network with underground packing in impassable channels. 1 - the plan/layout for route; 2- planning marks of the earth/ground; 3 - black/ferrous marks of the earth/ground; 4 - gradient/drafts (i) and distances (l); 5 - mark of the bottom of channel; 6 - type of channel; 7 - drain; 8 - channelization; 9 - water pipe; 10 - electric cable; 11 - relief mechanism; 12 - maximum level of ground water; К - camera/chamber No; NK - niche compensator; NO - fixed support.

Page 249.

During the construction of longitudinal section the minimum gradient/draft of thermal grid/networks is accepted:

(1) При подземной прокладке при отсутствии (2) грунтовых вод и при надземной прокладке	0,002
(3) При подземной прокладке в зоне грунтовых вод с попутным фильтрующим дренажем—в глинистых грунтах	0,002
(4) В песчаных грунтах	0,003
(5) При подземной прокладке в вечномерзлых грунтах	0,005—0,01
(6) При подземной прокладке в просадочных грунтах на ответвлениях к зданиям (от здания к камере ответвления)	0,02

Key: (1). With underground packing in the absence. (2). ground water and during above-ground laying. (3). With underground packing in the zone of ground water with incidental filtering drainage - in clay soil. (4). In sandy soils. (5). With underground laying in ever-frozen soils. (6). With underground packing in settled earth on branches to buildings (from building to the camera/chamber of branch).

With the packing of the thermal grid/networks through bridges and viaducts on the short sections of route is

allow/assumed the packing without gradient/draft.

With underground packing the gradient/draft of branches to separate buildings (input/introductions) it is expedient to accept towards the camera/chamber of thermal grid/network. For settled earth this condition is necessary. If the mark of the unit of branch is higher than the mark of entrance, before entrance at a distance not less than 5 m of it on branch is provided for the additional camera/chamber with the device of the gradient/draft of channel from building to the camera/chamber.

The mark of the bottom of channel on entrance is accepted higher than the mark of foundation level by value not less than on 500 mm.

With above-grade packing the gradient/draft of branches is fulfilled, as a rule, towards building.

Lowest points on the route of thermal grid/networks as far as possible one should place in such places where it is possible to carry out self-flowing derivation from the pipelines, the channels and the camera/chambers and from the systems of incidental drainage into downpour channelization, into basins and the absorbing wells.

As the exception/elimination is permitted removal of water into fecal channelization with the setting up of water lock on the self-flowing pipeline, which discharges water from the pit of the camera/chamber into channelization. In the case of the possibility of return current of water, is establish/installed the additionally disconnecting valve.

The possibility of derivation into the basins of public use is determined by sanitary regulations.

Derivation into the absorbing wells or the absorbing pits of the camera/chambers and tunnels can be realize/accomplished only with the well filtering soils and in the absence of ground water according to agreement with the organ/controls of sanitary supervision. With the impossibility of derivation, by gravity/of one's own accord are establish/installed constant drainage pumps with self-catching and launching/starting.

Pumpage from the pipelines of thermal grid/networks can it is produced by movable pumps.

12.3. Construction of pipelines.

The minimum distances between pipelines and the enclosing constructions in world/light in impassable channels one should accept not less indicated in Table 12.4.

The minimum distances between pipelines and the enclosing constructions in the world/light in of semiaccess channels and tunnels one should accept not less indicated in Table 12.5.

The distances between tubes on vertical line in passage and semiaccess channels are determined taking into account the height/altitude of support, dimensions of beam under the support of upper pipeline and thickness of isolation/insulation of lower pipeline. In this case, the clearance between the surfaces of isolation/insulation of pipelines one should accept according to Table 12.5.

During the determination of openings of tunnels and

semiaccess channels, they accept: the width of pass in world/light it is not less than 0.5 m for semiaccess channels even 0.7 m for passage tunnels; the height/altitude of channel in world/light it is not less than 1.4 m for semiaccess channels even 2 m for passage tunnels.

The distances between the surfaces of tubular insulation in plan/layout with above-grade packing should be accepted not the less corresponding distances of those who were indicated in Table 12.4.

During the determination of distances between the surfaces of insulation of pipelines and from the surface of isolation/insulation to structures on the flight (arms) of flexible compensators is considered the preliminary bracing of compensators and the nonsimultaneous warming up of adjacent pipelines.

In the cross section of impassable and semiaccess channels, all tubes are furnished in one horizontal series (Fig. 12.4).

In the cross section of the passage tunnels of large-diameter, tube they are furnished in a lower series.

In the common/general/total urban collector/receptacles of the tube of thermal grid/networks, they are placed in one vertical series on the wall, removed from the place of cable laying.

The arrangement/position of pipelines in the cross section of piers (Fig. 12.5) and of the separate masts (Fig. 12.6) must be such so that overloading of one of the sides of cross section does not exceed 30o/o of the assigned/prescribed load on the section/cut of pier or mast.

Table 12.4. Minimum clearances between pipelines and the structures of impassable channels.

(1) Диаметр трубопровода D_y в мм	(2) Минимальные расстояния в свету в мм			
	(3) от поверхности изоляции до стенки канала	(4) между поверхностями изоляции	(5) от поверхности изоляции до перекрытия канала	(6) от поверхности изоляции до дна канала
25—80	70	100	70	100
100—250	80	140	70	100
300—450	100	160	80	100
500—700	110	200	100	100
800—1200	120	—	100	100

Key: (1). Diameter of pipeline D_y in mm. (2). Minimum clearances in mm. (3). from the surface of isolation/insulation to the wall of channel. (4). between the surfaces of isolation/insulation. (5). from the surface of isolation/insulation to the overlap of channel. (6). from the surface of isolation/insulation to the bottom of channel.

Table 12.5. Minimum clearances between pipelines and structural constructions of semiaccess channels and tunnels.

(1) Диаметр трубопроводов D_y в мм	(2) Минимальные расстояния в свету в мм			
	(3) от поверхности изоляции до стенки канала или тоннеля	(4) между поверхностями изоляции по вертикали	(5) от поверхности изоляции до перекрытия канала или тоннеля	(6) от поверхности изоляции до дна канала или тоннеля
25—80	150	100	100	150
100—250	170	140	100	200
300—450	200	160	120	200
500—700	200	200	120	200
800—900	220	200	150	220
1000—1200	350	300	250	350

Key: (1). Diameter of pipelines D_y in mm. (2). Minimum clearances in mm. (3). from the surface of isolation/insulation to the wall of channel or tunnel. (4). between the surfaces of isolation/insulation on vertical line. (5). from the surface of isolation/insulation to the overlap of channel or tunnel. (6). from the surface of isolation/insulation to the bottom of channel or tunnel.

Page 250.

With the joint packing of thermal grid/networks with technological pipelines on multistage pier, the pipelines of thermal grid/networks, as a rule, are furnished in lower tier. During the multistage arrangement/position of thermal grid/networks in upper tier, lay large-diameter tubes (see Fig. 12.5).

During the arrangement/position of tubes in the cross sections of channels, tunnels, masts and piers one should consider the possibility of the convenient decoupling of flexible compensators. Tubes, on which are mounted flexible compensators with the greatest dimensions, they place in end position.

With the packing of water thermal grid/networks from starboard on the course of heat carrier from heat source, they place delivery pipe, and to the left - reverse/inverse on an entire route before input/introduction to users.

During the construction of pipelines in the camera/chambers and in the passage tunnels of clearance one should accept not less indicated in Table 12.6.

Height of the chamber and units of passage tunnels are accepted not less than 2 m. The decoupling of tubes in the units of passage tunnels is fulfilled in such a way that would be provided passages along the axis of tunnel, so, also, in the direction of passage branches. In this case, is allow/assumed local decrease in the dimensions of

pass in height/altitude to 1.2-1.4 m. If pass in the unit of pipelines is enclosed by lower run of pipes of branch, above them is arranged transfer metallic area/site with staircases.

With above-grade packing on low supports in the sites of installation of large catches with electric drive, is arranged ground-based closed pavilion.

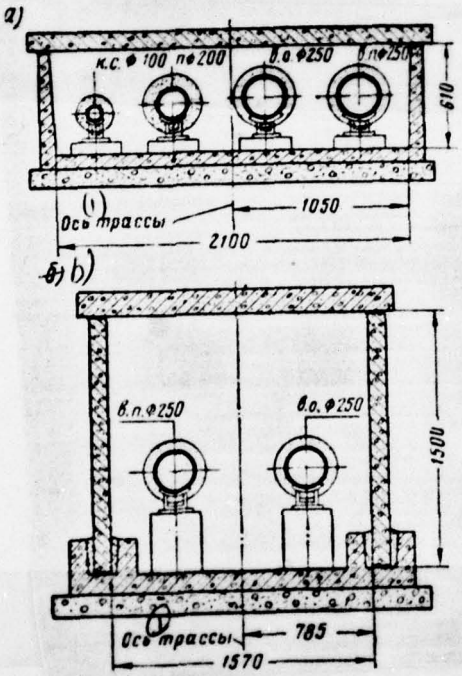


Fig. 12.4. Exemplary/approximate run of pipes in the cross sections of impassable and semiaccess channels. a) impassable channel; b) semiaccess channel; К. С. - condensate piping is self-flowing; Р - steam line; В.р. - water line feeding; В.о. - water line is reverse/inverse.

Key: (1). Axle/axis of route.

Table 12.6. Minimum clearances between structures and the units of pipelines in the camera/chambers and the tunnels.

(1) Наименование расстояний	(2) Минимальные расстояния в свету в мм
(3) От пола или от перекрытия камеры или тоннеля до поверхности изоляции труб (для перехода труб ответвлений)	0,7
(4) Боковые проходы для обслуживания арматуры и сальниковых компенсаторов (от стенки камеры до фланца арматуры или до компенсатора) при диаметрах труб до 500 мм	0,6
(5) То же, при диаметрах труб 600 мм и более	0,7
(6) От поперечной стенки камеры до корпуса сальникового компенсатора (со стороны стакана) при диаметрах труб до 500 мм	0,6 (вдоль оси трубы) (6a)
(7) То же, при диаметрах труб 600 мм и более	0,8 (вдоль оси трубы) (6a)
(8) От пола или перекрытия камеры или тоннеля до фланца арматуры или до сальникового компенсатора при диаметрах труб до 500 мм	0,3
(9) То же, при диаметрах труб 600 мм и более	0,4
(10) От пола или перекрытия до поверхности изоляции труб ответвлений	0,2

Key: (1). Designation of distances. (2). Minimum clearances in mm. (3). From sex/floor or from the overlap of the camera/chamber or tunnel to the surface of tubular insulation (for the transition of the tubes of branches). (4). Side passes for the maintenance of fixtures and gasket compensators (from chamber wall to the flange of reinforcement or to compensator) with the diameters of tubes to 500 mm. (5). the same, with the diameters of tubes 600 mm and more. (6). From transverse chamber wall to the housing of gasket compensator (from beaker/sleeve) with diameters of tubes to 500 mm. (6a). (along the axle/axis of tube). (7). The same, with the diameters of tubes 600 mm and more. (8). From sex/floor or overlap of the

camera/chamber or tunnel to the flange of reinforcement or to gasket compensator with the diameters of tubes to 500 mm. (9). The same, with the diameters of tubes 600 mm and more. (10). From sex/floor or overlap to the surface of the tubular insulation of branches.

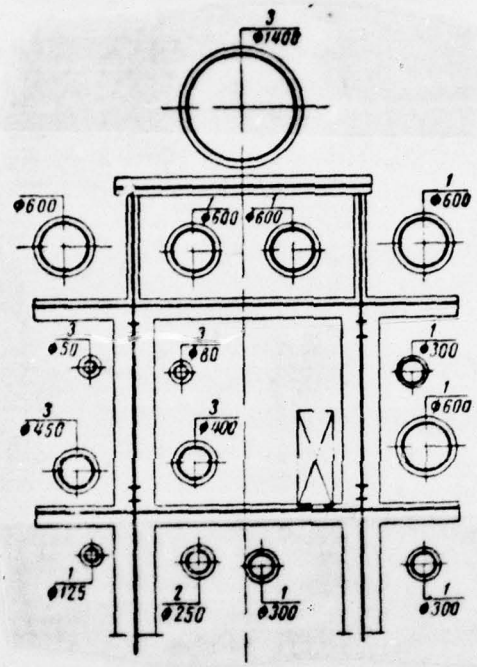


Fig. 12.5. Approximate run of pipes in the cross section of piers. 1 - steam line; 2 - condensate piping forcing; 3 - technological pipelines.

The same ground-based pavilion are arranged in the assemblies of the setting up of large catches with their underground packing (Fig. 12.7), if this is allow/assumed by the conditions of the passage of route. In the overlap of pavilions, is provided for the device for fastening of lifting devices (blocks and tackle, it is block-and-tackle, etc.).

In the assemblies of the setting up of catches (Fig. 12.8), gasket compensators (Fig. 12.9) and of sludge pans in the underground camera/chambers, stationary lifts are not provided for. Maintenance is produced by the crane trucks through the installation windows, the hatches or the camera/chambers.

The distance between centers of gasket compensators in the camera/chambers with diameters of tubes 500 mm and more is accepted of the conditions of the convenient replacement of gland packing and tightening of the bolts of the main bush (Fig. 12.9).

If the distance between centers of tubes on the adjacent the camera/chamber section of route is less than this is necessary for the arrangement/position of gasket

compensators, is allow/assumed device on run-back of the local branch/removal before gasket compensator with the shift/shear of axle/axis to value not more than $0.5\ D_y$.

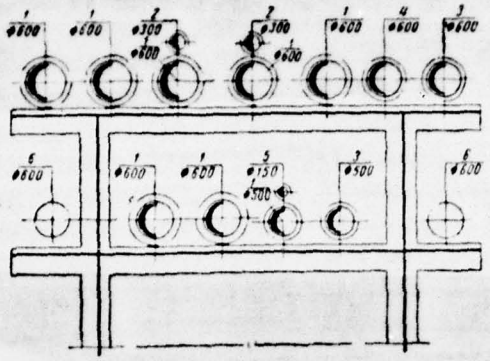


Fig. 12.6. Exemplary/approximate run of pipes on separate masts: 1 - steam line; 2 - condensate piping forcing; 3 - water line feeding; 4 - water line reverse/inverse; 5 - water line of the softened water; 6 - standby place.

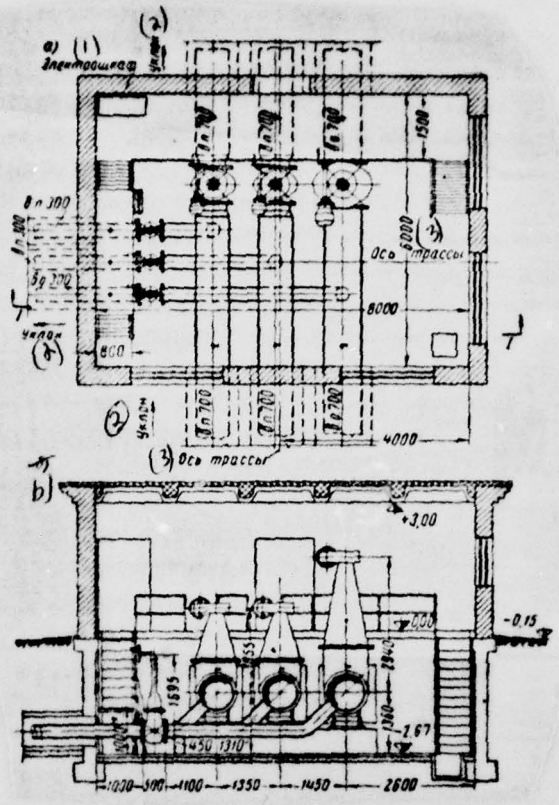


Fig. 12.7. Ground-based closed pavilion in the assemblies of the setting up of large catches on heating mains with their underground packing in impassable channels. a) plan/layout; b) cut/section with respect to I-I; V.P. - water line feeding; V.O. - water line is reverse/inverse.

Key: (1). electrical cabinet. (2). gradient/draft. (3). Axle/axis of route.

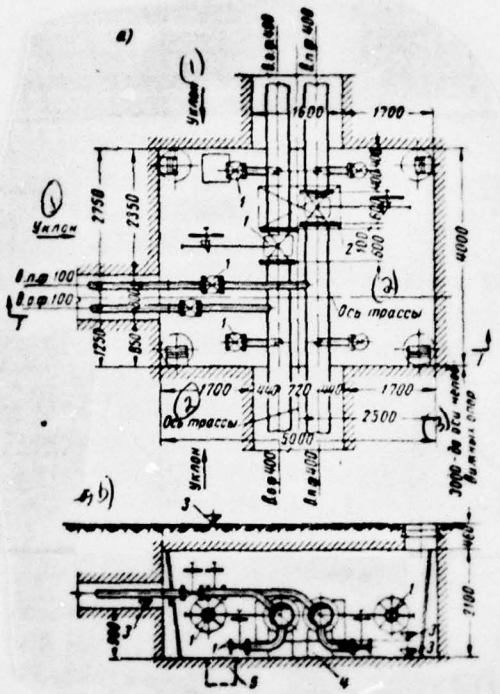


Fig. 12.8. Camera/chamber of thermal grid/network with the horizontal setting up of catches with hand drive. a) plan/layout; b) cut/section with respect to I-I; 1 - catch; 2 - installation window in the overlap of the camera/chamber; 3 - absolute marks of the bottom of the camera/chamber, bottom of channels and planning of the earth/ground; 4 - support under catches; 5 - pit 500 x 500 x 500 mm; V.p. - water line feeding; V.O. - water line is reverse/inverse.

Key: (1). Gradient/draft. (2). Axle/axis of route. (3). to the axle/axis of fixed supports.

Page 252.

Gasket compensators with the above-grade packing of thermal grid/networks on low supports are installed in t open air without any safety devices, but in the places, available to maintenance.

In camera/chambers and assemblies of passage channels with the arrangement of reinforcement at height/altitude t m of sex/floor, are arranged the run boards, equipped wi constant metallic ladders.

With the above-grade packing of the thermal grid/networks of area/site and staircase for the maintenan of equipment and reinforcement, they provide for only whe access to them from motor vehicles is hinder/hampered. Th minimum width of area/sites must ensure pass in world/lig not less than 0.6 m. On catches with electric drive, is arranged the protective housing.

Passage bridges along pier are erected on the sections of intersection of a large quantity of railway lines, rivers and in other places when access to pipelines from the earth/ground in the sites of installation of the reinforcement, which requires maintenance, is hinder/hampered.

In passage tunnels is provided for the device:

the suction and exhaust ventilation of periodic action;

constant artificial electric lighting with the value of illumination 5 lux for locations especially damp/crude and with the elevated temperature of air (for the illumination of the passage channels and camera/chambers in which it can penetrate gas, is applied the explosion-proof reinforcement);

entries and output/yields with staircases - at a distance nonmore than 300 m;

the ejection hatches for entry and output/yield of the tunnel at a distance are not more than 200 m and, furthermore, at all end points of the blind sections of

tunnel and in the assemblies where according to the designs of pipelines and reinforcement they are formed the closed area/sites, which do not have output/yield into tunnel, hatches as far as possible they are combined with ventilating shafts;

Installation windows - on all direct/straight sections of tunnels at a distance not more than 300 m (during overlap from stripper plates installation windows are not provided).

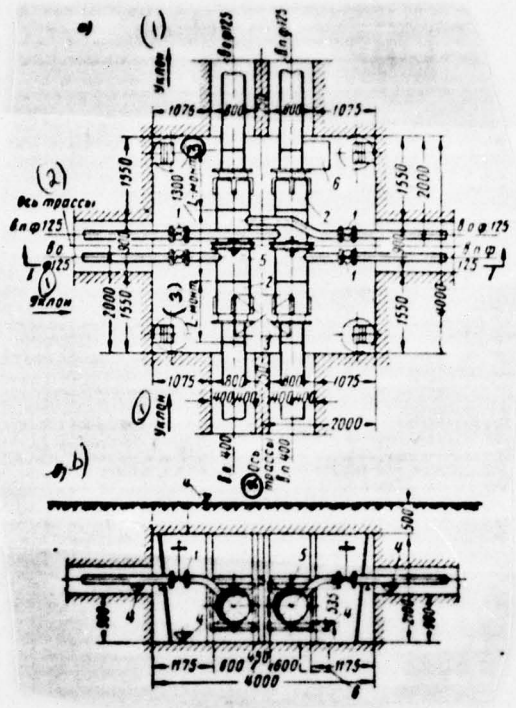


Fig. 12.9. Camera/chamber of thermal grid/network with gasket compensators and the built-in branch connections for the contiguity of the tubes of the branches of heating mains. a) plan/layout; b) cut/section with respect to I-I; 1 - catch; 2 - gasket compensators; 3 - assembling window into the covering of the camera/chamber; 4 - absolute marks of the bottom of the camera/chamber; the bottom of channels and planning of the earth/ground; 5 - fixed supports 6 - pit 500 x 500 x 500 mm; V.P. - water line feeding V.O. - water line is reverse/inverse.

Key: (1). Gradient/draft. (2). the axle/axis of route. (3) L.mont.

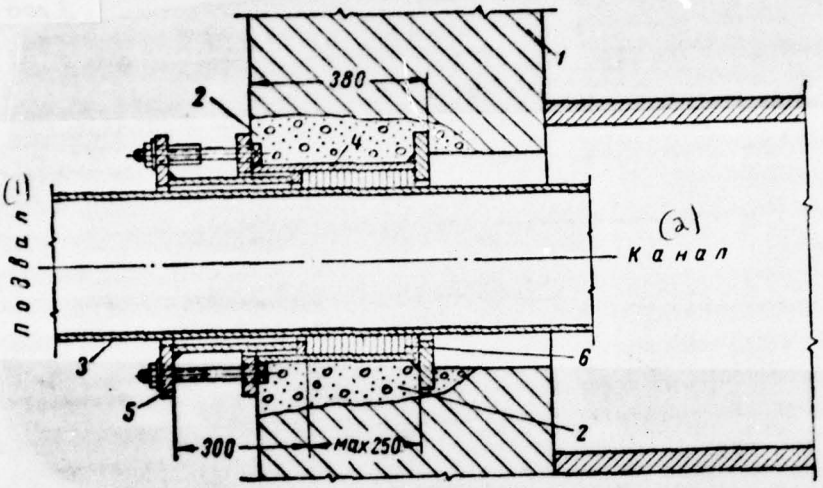


Fig. 12.10. Gas-impermeable gasket. 1 - wall of building; 2 - concrete of brand 100; 3 - tube; 4 - beaker/sleeve; 5 - gasket; 6 - ring gaskets of asbestos.

Key: (1). basement. (2). channel.

Page 253.

The size/dimension of the assembling windows: length is not less than 4 m, width according to the diameter of the greatest tube to field 0.1 m but is not less than 0.5 m.

Before the input/introductions of the pipelines of thermal grid/networks into buildings into tunnels and channels, one should establish/install hermetically sealed partition/baffles.

When, in the territory, residential areas and industrial enterprises of underground gas piping systems are present, it is necessary, furthermore, to provide for protection from possible penetration into the buildings of gas along the channels of thermal grid/networks. During arrangement/position within the wall of fixed support, the latter is fulfilled in the form of the solid monolithic reinforced-concrete panel, covering hole.

During the axial displacement of tubes within wall, are establish/installed the special gas-impermeable gaskets whose standard drawings are developed by Mosinzhproyekt (Fig. 12.10).

12.4. Ventilation of passage channels (tunnels).

The temperature of air in tunnels must not be above 50°C, and for the routine inspection and the repair of pipelines it is not more than 40°C.

If the temperature of air than higher indicated, is provided for the device of natural or mechanical ventilation.

In all cases constant hour exchange of air in tunnels must be not less single (SNIP II-G.10.62).

At the temperatures of air in tunnels to 40°C, ventilation is not erected. In this case the tunnels are aerated by the opening of hatches and entries.

Additional exchange of air for a reduction/descent in the temperature of air in tunnel from 50 to 40°C is achieved by movable ventilation installations.

The ventilation of tunnels is design/projected only for the distance/removal of the excesses of heat; moisture

removal (surplus air humidity) is not considered.

Mechanical ventilation is arranged only when natural ventilation does not provide the necessary effect. The given below procedure of calculation of the ventilation of the tunnels of thermal grid/networks is developed by the industrial constructio project. The calculation of the ventilation of tunnels is produced to the winter and summer conditions of the work of thermal grid/networks.

The calculation of the ventilation of tunnels is produced to the winter and summer conditions of the work of thermal grid/networks.

The calculated temperatures of surrounding air $t_{нар}$ are used: a) for determining the losses by the structures: during for winter conditions - the average monthly temperature of the coldest month $t_{нар} = t_x °C$; during for summer conditions - the average monthly temperature of the hottest month $t_{нар} = t_ж °C$;

b) for determining the exchange of air: during for winter conditions - the average monthly temperature of the coldest month $t_{нар} = t_x °C$; during on summer conditions - mean

temperature of the hottest month in 13 h $t_{нар} = t_{ж}$ °C.

The calculated temperatures of soil $t_{гр}$ for determining the losses by structures are accepted according to the natural temperature of soil at the depth of the axle/axis of tunnel; during calculation for the winter conditions of the work of thermal grid/networks - the average of the coldest month $t_{гр} = t_{гр.з}$ °C; during calculation for the summer conditions of the work of thermal grid/networks - the average of the hottest month $t_{гр} = t_{гр.л}$ °C.

The heat losses by structures into soil are determined from the formulas:

by one **meter of the tunnel**

$$w_к = a(t_к - t_{нар}) f_н + (bt_к - ct_{нар} - 0,4t_{гр}) f_{ст} + \\ + 0,85(t_к - t_{гр}) f_{дн} \text{ ккал}^{(1)}/ч; \quad (12.1)$$

Key: (1). kcal/h.

by the calculated **section**

$$W_к = w_к l_к \text{ ккал}^{(1)}/ч, \quad (12.2)$$

Key: (1). kcal/h

where $t_к$ is temperature of air in tunnel (channel) in °C; is the calculated temperature of surrounding air in °C; $t_{гр}$ is calculated natural temperature of soil at the depth of the axle/axis of tunnel (in world/light) in °C; $f_п$ is an internal surface of one meter of the overlap of tunnel in m²/m; $f_{ст}$ is the same for the walls of tunnel in m²/m; is the same, bottom of tunnel in m²/m; $l_к$ is length of the section of tunnel taking into account the expanded/scanned length of passage niches for U-shaped compensators in m; a, b, c - the coefficients, taken on Table 12.7.

The laying out of the territory of the USSR to climatic belts is accepted: Siberia, the northern Urals is I belt/zone, the middle strip of the European USSR the Far East - II - a belt/zone, the south part of the USSR - III belt/zone.

Heat releases by one meter of pipelines in tunnel are determined from the formula

$$q_{тр} = 1{,}1\Sigma q_i (t_i - t_к) \text{ ккал/ч}, \quad (12.3)$$

(1)

Key: (1). kcal/h

where q_i the specific heat losses by one meter of each

isolated/insulated pipeline in kcal/m² °C; t_i is the calculated temperature of the heat carrier of each pipeline in °C; 1.1 - the coefficient, which considers the additional heat losses by supports.

Total heat releases by pipelines are determined from the formula

$$Q_{тр} = q_{тр} l \text{ ккал/ч}, \quad (12.4)$$

(1)

Key: (1). kcal/h

where 1 is length of the section of pipeline taking into account the expanded/scanned length of U-shaped compensators in m.

Pipelines with the temperature of heat carrier t ≤ 40°C in calculations are not considered.

Heat releases in assemblies by reinforcement and gasket compensators are considered by increase to the common/general/total length of pipellines of equivalent lengths of the calculation of one meter for each reinforcement and compensator according to the diameter of the pipelines on which they are establish/installed.

The specific heat losses are accepted according to the indications which are given in Chapter 13.

Table 12.7. Correction factors depending on climatic belts and the conditions of work.

(1) Условия работы тепловых сетей	(2) Климатический пояс	(3) Значение коэффициентов		
		a	*b*	*c*
(4) Летом	I; II; III	0,9	1,2	0,8
(5) Зимой	I; II	0,65	1,1	0,7
	III	0,9	1,2	0,8

Key: (1). Work conditions of thermal grid/networks. (2). Climatic belts. (3). Value of coefficients. (4). in summer. (5). In winter.

Page 254.

In the absence of ventilation, the temperature of air in tunnel is determined from the equation of heat balance for the formula

$$t_в = \frac{1{,}1\sum q_i t_i + a t_{гр} f_п + c t_{нар} f_{ст} + \\ + 0{,}4 t_{гр} f_{ст} + 0{,}85 t_{гр} f_{дн}}{a f_п + b f_{ст} + 0{,}85 f_{дн} + 1{,}1\sum q_i} \rightarrow \\ \leftarrow \frac{}{a f_п + b f_{ст} + 0{,}85 f_{дн} + 1{,}1\sum q_i}. \quad (12.5)$$

The calculated air volume for the ventilation of passage channels is determined for the winter and summer conditions of the work of thermal grid/networks, if the temperature of air in tunnel, calculated according to equation (12.5) for winter period, is obtained above than for a summer period. If the higher temperature of air is

obtained for a summer period, the calculated air volume for ventilation is determined only for summer conditions of the work of thermal grid/networks.

the air volume at the temperature of air in tunnel above +40°C are determined according to the value of the excesses of heat to entire calculated section according to the formula

$$V = \frac{Q_{тр} - W_к}{0{,}3(t_{ух} - t_{нар})} м^3. \qquad (12.6)$$

where $t_{нар}$ is the calculated temperature of the surrounding air, entering into tunnel, in °C; $t_{ух}$ - the calculated temperature of the outgoing from tunnel air is accepted 40°C.

The heat releases and the heat losses, entering the formula (12.6), are calculated with average temperature of air in the channel of equal to:

$$t_к^{ср} = \frac{t_{ух} + t_{нар}}{2} °C. \qquad (12.7)$$

The losses of head of air in ventilation system are determined according to the sum of losses of head of supply and exhaust shaft/mines with grid/cascades and of tunnel itself.

In this case, the equivalent diameter of pass in tunnel is determined from the formula

$$D_{экв} = \frac{2hk}{h+k} \text{ мм}, \qquad (12.8)$$

where h is a height/altitude of tunnel in mm; k is average width of the free pass between the surfaces of isolation/insulation in tunnel in mm.

Ventilating shafts one should, as a rule, combine with the entries into tunnel.

The height/altitude of the separate exhaust shaft/mines must not exceed 6-7 m above ground level. During accomplishing of shaft/mines attached to buildings the height/altitude of shaft/mines is determined by the height/altitude of buildings (Fig. 12.11).

Exhaust shaft/mines one should furnish in the first place at the end points of the blind sections of tunnels and in the assemblies of the pipelines, which have considerable heat releases. On the remaining sections of tunnel, the distance between exhaust shaft/mines is accepted about 100 m.

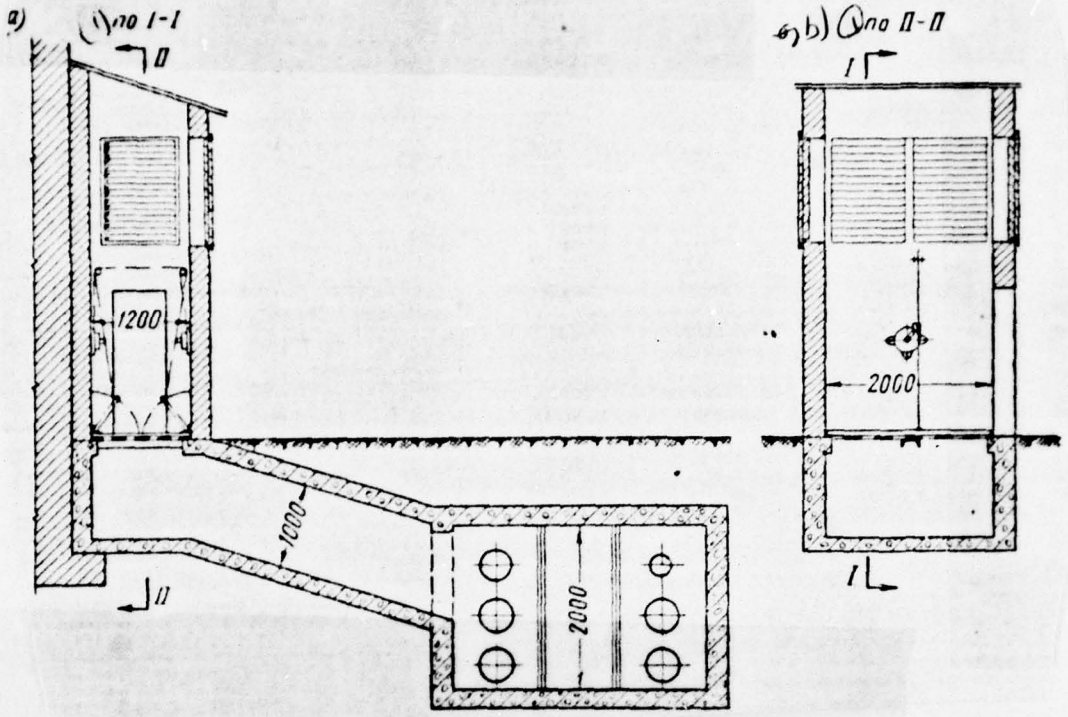


Fig. 12.11. Exhaust shaft/mine of the wall of building. a) cut/section on I-I; b) cut/section on II-II.

Key: (1). On.

Page 255.

Supply shaft/mines they place between exhaust at a distance of approximately 50 m and as far as possible

unite with the ejection hatches (Fig. 12.12).

The bottom of supply grid/cascade must be at height/altitude not less than 0.6 m of the earth's surface.

Exhaust shaft/mines with the considerable gradient/draft of tunnel one should arrange at peaks, and supply - at the lowest points of tunnel.

The arrangement of ventilating shafts must be connected with Planning and building-up of territory on the route of tunnel.

Exhaust and supply shaft/mines are supplied with valves or dampers for the regulation of inflow and drawing of air, and also for the complete closure of shaft/mines.

Fans with electric motors is recommended the establish/installing of in exhaust shaft/mines with the bypass valves, which ensure natural ventilation in transfer and winter the operating cycles of thermal grid/networks.

During mechanical ventilation are applied axial-flow blowers with electric motor in one axle/axis. A quantity of

fans is accepted according to the number of working fans without reserve.

Electric motors apply the shielded series A2 (for damp/crude locations) and the closed blown off/out series A02 with manual control and with switching of the direction of rotation of fans from drawing to inflow and back (Fig. 12.12).

To the time of the production of repair work in the separate camera/chambers and the assemblies, can be applied mechanical movable ventilation installation.

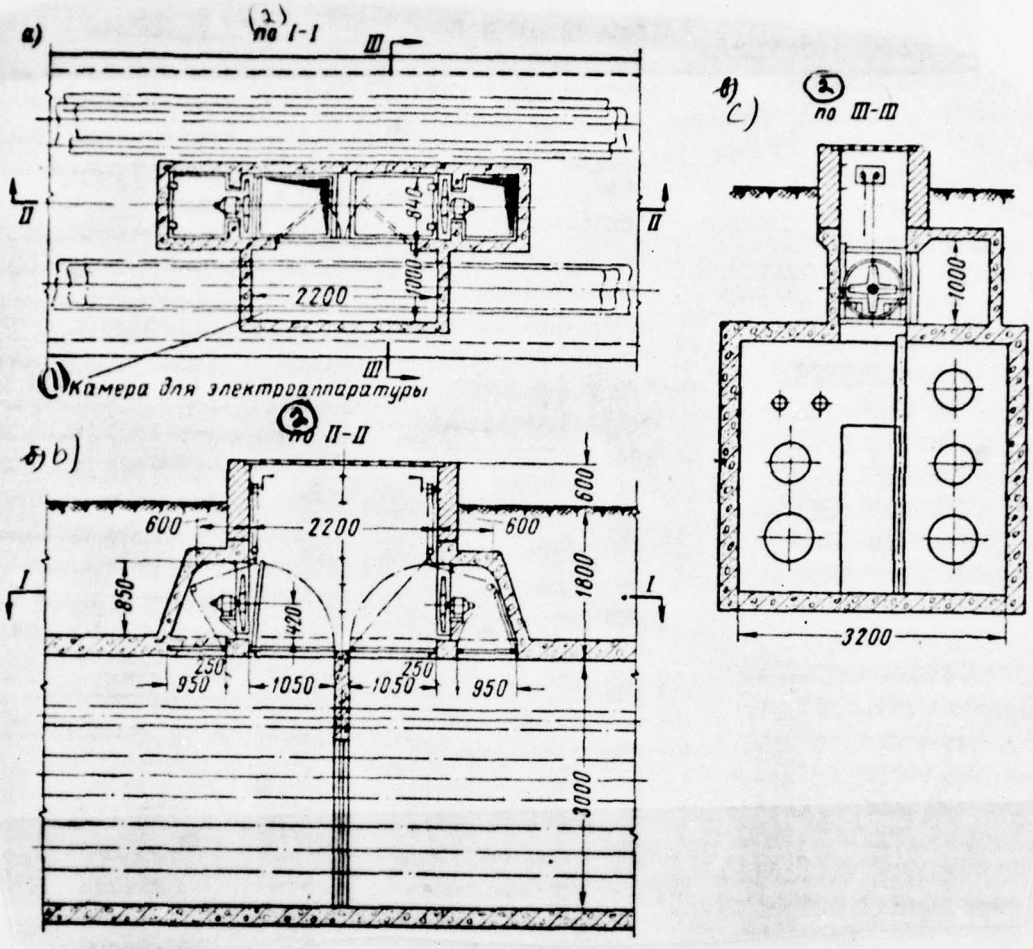


Fig. 12.12. Open supply shaft/mine. a) plan/layout with respect to I-I; b) cut/section with respect to II-II; c) cut/section with respect to III-III.

Key: (1). Camera/chamber for electrical equipment. (2). on.

SUBJECT CODE 5471D

Page 256.

Chapter 13.

HEAT INSULATION.

13.1. Materials.

The maximum temperatures of application/use, specific weight and the coefficients of the thermal conductivity of the base layer of thermal insulation constructions are given in Table 13.1.

Mean temperatures of the base layer of insulation construction are accepted according to table 13.2.

With underground packing the coefficient of the thermal

conductivity of soil is determined on the basis of the data of research or approximately on table 13.3.

Thermal insulation constructions from piercing mineral wool materials for conduit/manifolds must have in upper part the distributed supports from strong materials.

2. With underground packing are calculated coefficient of thermal conductivity of base layer of isolation/insulation determines with coefficient of k = 1.2, which considers moisture of thermal insulation constructions.

Key: (1). Designation of the material of thermal insulation layer in construction. (2). Maximum temperature of application/use in °C. (3). The specific weight of a layer of basic insulation in construction (without fasteners) in kg/m³. (4). The coefficient of thermal conductivity in kcal/m h deg (is not more than). (5). Alfol corrugated. (6). Asbestos cord GOST-1779-55. (7). Mineral wool piercing articles of mark/brand. (8). Mineral wool moldings on the organic trusses (phenolic resin) (GOST [- All-union State Standard] 9573-60) of brand 150. (9). Mineral wool articles on inorganic trusses GOST-5742-51. (10). Foam concrete articles are nonautoclave. (11). The same. (12). Foam concrete or reinforced foam concrete articles are autoclave. (13). Sovelite articles GOST 6788-53 of mark/brand. (14). The same, mark/brand. (15). Vulcanite articles GOST 10179-62 of mark/brand. (16). Diatomaceous articles fired (GOST 2694-52) mark/brands. (17). Ceramic cellular/honeycomb in blocks. (18). The slag cotton of brand

150 (GOST 4640-61) into packing under grid on rings made of heat insulation articles. (19). Glass-wadded piercing articles (GOST 2245-43), republished into 1952) of mark/brand. (20). Plaster layer asbestos zurite or gypsum. (21). Plaster layer from bitumen pastes, a layer from the mastic asphalt. (22). A plaster layer is asbestos cement. (23). Anticorrosion layer insulating material or bituminous-rubber waterproofing material.

Table 13.1. Maximum temperature of application/use, specific weight and the coefficients of the thermal conductivity of the base layer of thermal insulation constructions in dry state depending on mean temperature.

(1) Наименование материала теплоизоляционного слоя в конструкции	(2) Предельная температура применения в °С	(3) Объемный вес слоя основного изоляционного материала в конструкции (без крепежных деталей) в кг/м³	(4) Коэффициент теплопроводности в ккал/м ч град (не более)
1	2	3	4
Альфоль гофрированный	350	20—40	$0,051+0,0022\ t_{ср}$
Асбестовый шнур (ГОСТ 1799—55)	400	700—900	$0,120+0,00020\ t_{ср}$
Минераловатные прошивные изделия марки 200 (ТУ 31-62 МС РСФСР)	600	240—250	$0,046+0,00016\ t_{ср}$
Минераловатные формованные изделия на органических связках (фенольных смолах) (ГОСТ 9573—60) марки 150	300	175	$0,044+0,00017\ t_{ср}$
Минераловатные изделия на неорганических связках	600	350—400	$0,053+0,00017\ t_{ср}$
Пенобетонные изделия неавтоклавные (ГОСТ 5742—51)	200	400	$0,094+0,00026\ t_{ср}$
То же	200	500	$0,109+0,00026\ t_{ср}$
Пенобетонные или армопенобетонные изделия автоклавные	200	400	$0,090+0,00020\ t_{ср}$
Совелитовые изделия марки 350 (ГОСТ 6788—53)	500	350	$0,065+0,00016\ t_{ср}$
То же, марки 400	500	400	$0,067+0,00016\ t_{ср}$
Вулканитовые изделия марки 350 (ГОСТ 10179—62)	600	350	$0,057+0,0016\ t_{ср}$
То же, марки 400	600	400	$0,070+0,00015\ t_{ср}$
Диатомовые изделия обожженные (ГОСТ 2694—52) марки 500	900	500	$0,100+0,00020\ t_{ср}$
Керамика ячеистая в блоках	900	500	$0,100+0,00025\ t_{ср}$
Минеральная вата марки 150 (ГОСТ 4640—61) в набивку под сетку на кольцах из теплоизоляционных изделий	600	260	$0,050+0,00016\ t_{ср}$
Стекловатные прошивные изделия (ГОСТ 2245—43, переизданный в 1952 г.) марки 170	300	200	$0,036+0,00020\ t_{ср}$
Штукатурный слой асбозуритовый или гипсовый	—	850—900	0,2 при 50° С
Штукатурный слой из битумных паст, слой из асфальтовых мастик	—	1150	0,25 при 50° С
Штукатурный слой асбестоцементный	—	1600—1900	0,33 при 50° С
Антикоррозийный слой изоловый или бриволовый	—	1000—1100	0,15—0,2 при 50—70° С

Notes: 1. With underground packing without the air space of the value of the coefficient of the thermal conductivity of a plaster layer and construction enclosure/protections, they accept different to the coefficient of the thermal conductivity of the ground.

Page 257.

Table 13.2. Mean temperatures of the base layer of insulation constructions.

(2) Температура окружающей среды в °С	(1) Температура теплоносителя t в °С						
	50	100	150	200	250	300	350
	$t_{ср}=\frac{t+t_{нв}}{2}$ в °С						
+40	50	76	100	130	155	180	210
+25	44	70	95	125	150	175	205
+15	39	65	90	120	145	170	200
+5	36	62	63	113	138	163	193
0	33	60	80	110	135	160	190
−15	27	55	75	105	130	155	185
−30	22	45	65	95	120	145	175

Notes 1: with underground packing in impassable and semiaccess channels, the ambient temperature is taken equal to the temperature of air in channel.

2. At underground channel-free packing ambient temperature is accepted equal to temperature of soil at depth of laying of axle/axis of conduit/manifold.

Key: (1). Temperature heat carriers t in °C. (2). Ambient tempesature in °C.

Table 13.3. Coefficients of the thermal conductivity of soil at depth 1.5 m at temperature of +5°C.

(1) Характеристика грунтовых условий						
(2) классификация по влажности	(3) вид грунта	(4) объемный вес сухой массы грунта в кг/м³	(5) расчетная абсолютная влажность грунта в %	(6) расчетная влажность грунта на стыке с изоляцией в %	(7) коэффициент теплопроводности грунта с учетом его влажности $\lambda_{гр}$ в ккал/м ч град	усредненный расчетный коэффициент теплопроводности грунта $\lambda_{гр.\ расч}$ в ккал/м ч град
Маловлажный (11)	Глинистые и суглинки (9)	1600 2000	5 5	0 0	0,75 1,5	1,5
	Пески и песчаные (10)	1600 2000	5 3	0 0	0,95 1,5	
	Крупнообломочные (щебенистые и гравийные) (12)	2000	5	0	1,75	
	Скальные (13)	2400	1	0	2	
Влажный (16)	Глинистые и суглинки (14)	1600 2000	20 10	10 2	1,5 2,2	2
	Пески и песчаные (15)	1600 2000	15 5	14 4	1,65 1,75	
	Крупнообломочные (щебенистые и гравийные) (17)	2000	8	4	2,35	
	Скальные (18)	2400	3	1,5—2	3	
Водонасыщенные (21)	Глинистые и суглинки (19)	1600 2000	23,8 11,5	23,8 11,5	1,6 2,3	2,5
	Пески и песчаные (20)	1600 2000	23,8 11,5	23,8 11,5	2,1 2,9	
	Крупнообломочные (щебенистые и гравийные) (22)	2000	11,5	11,5	2,9	
	Скальные (23)	2400	3,3	3,3	4	

Key: (1). Characteristic ground conditions. (2). classification on humidity. (3). the form of soil. (4). the specific weight of the dry mass of soil in kg/m³. (5). the calculated absolute humidity of soil in o/o. (6). the calculated humidity of scil on joint with isolation/insulation in o/o. (7). the coefficient of the thermal conductivity of soil taking into account its humidity λ_{rp} in kcal/m h deg. (8). the averaged calculated coefficient of the thermal conductivity of the soil of calc. in kcal/m h deg. (9). Clay and loams. (10). Sands and sand. (11). Low-moisture. (12). Large-fragment (rubble and gravel). (13). Rock. (14). Clay and loams. (15). Sands and sand. (16). Moist. (17). Large-fragment (rubble and gravel). (18). Rock. (19). Clay and loams. (20). Sands and sand. (21). Water-saturated. (22). Large-fragment (rubble and gravel). (23). Rock.

Page 258.

Table 13.4. Norms of the losses by the isolated/insulated conduit/manifolds indoors and tunnels with the calculated temperature of air $t_н$ within limits from 20 to 40° C.

(1) Наружный диаметр труб в мм	(2) Температура теплоносителя в °С (среднегодовая или среднесезонная)					
	50	70	100	150	250	350
	(3) Потери тепла в ккал/м ч, не более					
32	12	18	28	43	74	105
57	14	21	32	53	90	127
76	15	24	37	58	99	141
89	16	25	39	62	105	149
108	22	32	45	68	113	160
133	27	37	53	76	126	176
159	31	42	60	84	110	192
219	38	49	70	100	165	227
273	42	55	78	111	183	253
325	45	61	85	122	200	278
377	50	66	92	131	218	300
426	53	71	98	140	235	322
478	60	78	109	155	253	349
529	66	85	120	170	270	375
630	82	104	140	195	310	425
720	95	119	160	220	340	470
820	110	138	180	250	380	515
920	135	159	205	275	415	555
1020	150	182	225	300	450	600
1220	180	208	260	350	515	690

Key: (1). Outside diameter of tubes in mm. (2). The temperature of heat carrier in °C (mean annual or mean seasonal). (3). The heat losses in kcal/m h, are not more.

Table 13.5. Norms of the losses by the isolated/insulated conduit/manifolds in the open air with the calculated temperature of air $t_н = 0 - 10°C$ and isolated/insulated by steam

condensers of underground packing in impassable channels at the calculated temperature of soil at the depth of laying

$t_{гр.ср.год} = +5°C$

(1) Наружный диаметр труб в мм	(2) Температура теплоносителя в °С (среднегодовая или среднесезонная)					
	50	70	100	150	250	350
	(3) Потери тепла в ккал/м ч, не более					
32	15	24	31	46	77	108
57	21	28	40	58	96	134
76	25	33	45	66	108	148
89	28	36	50	71	114	158
108	31	41	55	77	125	172
133	35	46	60	85	136	188
159	38	48	65	94	148	205
219	46	57	78	110	175	240
273	53	67	87	125	198	268
325	60	76	100	140	220	300
377	71	89	114	156	240	326
426	82	100	128	173	260	352
478	89	108	136	185	280	375
529	95	115	145	196	300	400
630	104	127	160	218	330	440
720	115	139	176	238	358	480
820	135	161	200	266	398	535
920	155	183	225	296	440	585
1020	180	212	255	330	485	640
1220	205	239	290	380	560	740

Key: (1). Outside diameter of tubes in mm. (2). The temperature of heat carrier in °C (mean annual or mean seasonal). (3). The heat losses in kcal/m h, are not more.

Table 13.6. The norms of the losses by the isolated/insulated conduit/manifolds of the water thermal grid/networks of underground packing, arrange/located in inpassable channels it is channel-free.

(1) Наружный диаметр труб $d_н$ в мм	(2) Обратная магистраль, $t_{ср}$=50°C $q_{l_{обр}}$ в ккал/м ч	(3) Подающая магистраль, $t_{макс}$=95°C; $t_{мин}$=40°C; $t_{ср}$=65°C $q_{l_{под}}$ в ккал/м ч	(4) Суммарные потери тепла при двухтрубной прокладке $q_{l_{под}}+q_{l_{обр}}$ в ккал/м ч	(5) Подающая магистраль, $t_{макс}$=150°C; $t_{мин}$=70°C; $t_{ср}$=90°C $q_{l_{под}}$ в ккал/м ч	(6) Суммарные потери тепла при двухтрубной прокладке $q_{l_{под}}+q_{l_{обр}}$ в ккал/м ч	(7) Подающая магистраль, $t_{макс}$=180°C; $t_{мин}$=90°C; $t_{ср}$=100°C $q_{l_{под}}$ в ккал/м ч	(8) Суммарные потери тепла при двухтрубной прокладке $q_{l_{под}}+q_{l_{обр}}$ в ккал/м ч
	(9) не более						
32	20	25	45	32	52	38	58
57	25	31	56	40	65	47	72
76	29	35	64	45	74	53	82
89	31	38	69	49	80	57	88
108	34	42	76	54	88	62	96
159	42	52	94	65	107	75	117
219	51	62	113	79	130	91	142
273	60	72	132	90	150	103	163
325	68	81	149	100	168	115	183
377	76	—	—	107	183	126	202
426	82	—	—	121	203	137	219
478	91	—	—	132	223	150	241
529	101	—	—	142	243	160	261
630	114	—	—	163	277	184	298
720	125	—	—	181	306	202	327
820	141	—	—	200	341	223	364
920	155	—	—	218	373	244	399
1020	170	—	—	240	410	266	436
1220	199	—	—	280	479	309	508

Key: (1). Outside diameter of tubes in mm. (2). Reverse/inverse main line, in kcal/m h. (3). The feed pipe, in kcal/m h. (4). Total heat losses with two-funnelled packing in kcal/m h. (5). The feed pipe, in kcal/m h. (6). Total heat losses with two-funnelled packing in kcal/m h. (7). The feed pipe, in kcal/m h. (8). Total heat losses with two-funnelled packing in kcal/m h. (9). it is not more.

Page 259.

Layers of the mineral wool and glass-wadded materials of piercing, on synthetic trusses and without them in composite or printed insulation constructions must be consolidated to the specific weight, given in graph/count 3 tables 13.1 on the basis of the data of chapter SNIP [- Construction norms and regulations] N G.10-62.

According to the indications of the same chapter SNIP of the thickness of insulation constructions, they must be establish/installed on the basis of the technical and economic calculations or according to the effective norms of the losses. Tables 13.4-13.6 give the norms of the losses by the conduit/manifolds of thermal grid/networks at the average annual values of the temperatures of the heat carrier and the environment, affirmed by the technical review board of the Ministry of Cconstruction of power statipns.

The values of the losses at the maximum and other

assigned/prescribed temperatures of heat carrier and the corresponding ambient temperature are determined from the formula

$$q_l = q_{l\,норм} \frac{t - t_{окр.ср}}{t_{ср} - t_{окр.средгод}} \text{ kcal/m h}, \qquad (13.1)$$

where q_l are losses of heat 1 m of heating main at the maximum or other assigned/prescribed temperature of heat carrier t in kcal/m h;

$q_{l\,норм}$ – the loss of heat 1 m of heating main on norms at the average annual temperature of heat carrier $t_{ср}$ in kcal/m h;

$t_{окр.ср.год}$ – an ambient temperature (air $t_н$ or soil $t_{гр}$), by which are given the norms of the losses of heat in °C;

$t_{окр.ср}$ – an ambient temperature at the maximum or other assigned/prescribed temperature of heat carrier in °C.

13.2. Determination of thermal resistance and thicknesses of insulation construction.

The complete thermal resistance of the which is subject to isolation/insulation conduit/manifold determines according to the norms of the losses according to the formula

$$R_l = \frac{t - t_0}{q_l} \text{ m h deg/kcal,} \qquad (13.2)$$

where t is temperature of heat carrier in °C;

t_0 - the ambient temperature in °C;

q_l - the norm of the losses by the isolated/insulated conduit/manifold in kcal/m h.

The losses of heat by the isolated/insulated conduit/manifold determine from the same formula (13.2) according to the known complete thermal resistance of the insulation construction:

$$q_l = \frac{t - t_0}{R_l} \text{ kcal/m h.} \qquad (13.3)$$

The complete thermal resistance of the isolated/insulated conduit/manifold of the superheated steam of large

extent/elongation determine according to the permissible temperature drop pair according to the formula

$$R_l = \frac{\frac{l_p}{G}}{c_p \ln \frac{t_{нач} - t_0}{t_{кон} - t_0}} \quad \text{m h deg/kcal} \qquad (13.4)$$

where $t_{нач}$ and $t_{кон}$ - temperature is pair in the beginning and end of the designed section in °C;

t_0 - the ambient temperature in °C;

G - calculated consumption pair on the designed section and kg/h;

c_p - heat capacity pair at average pair meters on section in kcal/kg deg;

l_p - the calculated length of steam line, is equal to $l_p = \beta l$, in m;

l - the length of the section of steam line according to the plan in m;

β is the coefficient, which considers the additional heat losses by supports, fittings and compensators (table 13.7).

Table 13.7. Values of coefficient β.

(1) Способ прокладки	(2) Тепловые сети	
	(3) магистральные	(4) распределительные и ответвления к отдельным зданиям
Бесканальная (5)	1,1	1,15
В помещениях, тоннелях (6)	1,15	1,25
Наземная (7)	1,2	1,3

Key: (1). Method of packing. (2). Thermal grid/networks. (3). main-line. (4). distributive and branch to separate buildings. (5). Channel-free. (6). In locations, tunnels. (7). Above-grade.

изолированных теплопроводов в *м ч град / ккал*

сопротивление			
(5) канала и грунта $R_{l_{кан}} = \Sigma$			
(10) теплоотдачи от воздуха к стенке канала $R_l^{кан} = \frac{1}{\alpha_{кан} \pi d_{экв\text{-}кан}}$ (13.9)	(11) грунта для канала $R^{гр}_{l_{кан}} = \frac{\ln \frac{4h}{d_{экв\text{-}кан}}}{2\pi\lambda_{гр}}$ (13.10)	(12) взаимного влияния труб при двухтрубной прокладке $R_{l_{1,2}}$ (13.11)	(13) Полное термическое сопротивление изолированного теплопровода R_l в *м ч град ккал*
–	–	–	$R_l = \Sigma$ (13.22)
–	–	–	$R_l = \Sigma$ (13.23)
–	–	$R_{l_{1,2}} = \psi R_{1,2} = \psi \frac{\ln \sqrt{1+\left(\frac{2h}{k}\right)^2}}{2\pi\lambda_{гр}}$	$R_l = \Sigma$ (13.24) и (13.25)
$R_l^{кан}$	$R^{гр}_{l_{кан}}$	–	$R_l = \Sigma$ (13.26)
$R_l^{кан}$	$R^{гр}_{l_{кан}}$	$R_{l_{1,2}} = \psi_{кан} R_{l_{кан}}$	$R_l = \Sigma$ (13.27) и (13.28)
$R_l^{яч.кан}$	$R^{гр}_{l_{яч.кан}}$	$R_{l_{1,2}} = \psi R_{1,2} = \psi \frac{\ln \sqrt{1+\left(\frac{2h}{k}\right)^2}}{2\pi\lambda_{гр}}$	$R_l = \Sigma$ (13.29) и (13.30)
$R_{l_1}^{кан}$	$R^{гр}_{l_{кан}}$	$R_{l_{1,2}} = \psi_1 R_{1,2} = \psi_1 \frac{\ln \sqrt{1+\left(\frac{2h}{k}\right)^2}}{2\pi\lambda_{гр}}$	$R_{l_{под}} = \Sigma$ (13.31)
–	–	$R_{l_{2,1}} = \psi_2 R_{1,2}$	$R_{l_{обр}} = \Sigma$ (13.32)
(29) Прокладка в непроходных одноячейковых каналах			
$\psi_{1кан} = \frac{(t_2 - t_{гр}) R_{l_{тр}} + (t_1 - t_2) R_{l_{кан}}}{(t_1 - t_{гр}) R_{l_{тр2}} + (t_1 - t_2) R_{l_{кан}}}$ (13.14)		$\psi_{2кан} = \frac{(t_1 - t_{гр}) R_{l_{тр2}} + (t_1 - t_2) R_{l_{кан}}}{(t_2 - t_{гр}) R_{l_{тр1}} - (t_1 - t_2) R_{l_{кан}}}$ (13.15)	
$\psi_{1кан} = \frac{q_{l_2}}{q_{l_1}}$ (13.20)		$\psi_{2кан} = \frac{q_{l_1}}{q_{l_2}}$ (13.21)	

Pages 260-261

Table 13.8. Complete thermal resistance of the isolated/insulated heating mains in the various forms of packing.

(6) Вид прокладки теплопроводов	(1) Составляющие полного термического сопротивления (2) Термическое (3) изоляционной конструкции теплопровода $R_{l_{тр}} = \Sigma$			(4) грунта для изолированной трубы
	(7) основного изоляционного слоя $R_l^{из} = \frac{\ln \frac{d_{из}}{d_н}}{2\pi\lambda_{из}}$ (13.5)	(8) покровного слоя $R_l^{п} = \frac{\ln \frac{d_к}{d_{из}}}{2\pi\lambda_п}$ (13.6)	(9) теплоотдачи в окружающий воздух $R_l^{н} = \frac{1}{\alpha_н \pi d_к}$ (13.7)	$R_l^{н} = R_l^{гр} = \frac{\ln \frac{4h}{d_к}}{2\pi\lambda_{гр}}$ (13.8)
1. Воздушная (14)	$R_l^{из}$	$R_l^{п}$	$R_l^{н}$	–
2. Бесканальная однотрубная (15)	$R_l^{из}$	–	–	$R_l^{гр}$
3. Бесканальная двухтрубная (16)	$R_l^{из}$	–	" –	$R_l^{гр}$
4. В непроходном канале однотрубная (17)	$R_l^{из}$	$R_l^{п}$	$R_l^{н}$	–
5. В непроходном одноячейковом канале двухтрубная (18)	$R_l^{из}$	$R_l^{п}$	$R_l^{н}$	–
6. В непроходном двухъячейковом канале двухтрубная (19)	$R_l^{из}$	$R_l^{п}$	$R_l^{н}$	–
7. Подающий теплопровод в одноячейковом непроходном канале (20)	$R_{l_1}^{из}$	$R_{l_1}^{п}$	$R_{l_1}^{н}$	–
8. Обратный теплопровод бесканальной прокладки (21)	$R_{l_2}^{из}$	–	–	$R_{l_2}^{гр}$
Значения коэффициентов ψ и $\psi_{кан}$ для подающего и обратного теплопроводов двухтрубной прокладки (22)	(23) Варианты расчетов	(24) Прокладка бесканальная и в двухъячейковых каналах		
	I – при известной конструкции (26)	$\psi_1 = \frac{(t_1 - t_{гр})R_{l_2} - (t_2 - t_{гр})R_{l_1,2}}{(t_1 - t_{гр})R_{l_1} - (t_2 - t_{гр})R_{l_1,2}}$ (13.12)*		$\psi_2 = \frac{(t_1 - t_{гр})R_{l_2} - (t_2 - t_{гр})R_{l_1,2}}{(t_2 - t_{гр})R_{l_1} - (t_1 - t_{гр})R_{l_1,2}}$ (13.13)
	II – при известных потерях тепла (27)	$\psi_1 = \frac{q_{l_2}}{q_{l_1}}$ (13.18)		$\psi_2 = \frac{q_{l_1}}{q_{l_2}}$ (13.19)

* $R_{l_1} = R_{l_{под}} - R_{l_{1,2}}$ (13.16)

$R_{l_2} = R_{l_{обр}} - R_{l_{2,1}}$ (13.17)

Key: (1). Comprising of the complete thermal resistance of the isolated/insulated heating mains in m h deg/kcal. (2). Thermal resistance. (3). the insulation construction of heating main $R_{l_{тр}} = \Sigma$ (4). soil for the isolated/insulated tube. (5). channel and soil $R_{l_{кан}} = \Sigma$ (6). Form of the packing of heat conductors. (7). basic insulating layer. (8). a cover layer. (9). heat emission into surrounding air. (10). heat emission from air to the wall of channel. (11). soil for a channel. (12). the mutual effect of tubes with two-funnelled packing. (13). Complete thermal resistance of the isolated/insulated heating main R_l в м ч град/ккал in m h deg/kcal. (14). Air. (15). Channel-free is single-pipe. (16). Channel-free two-pipe. (17). In impassable channel is single-pipe. (18). In impassable unicellular channel is two-funnelled. (19). In impassable two-cell channel is two-funnelled. (20). Feeding heating main in unicellular impassable channel. (21). Reverse/inverse heat conductor channel-free of packing. (22). Values of coefficients ψ and for the feeding and reverse/inverse heating mains of $\psi_{кан}$ two-funnelled packing. (23). Versions of calculations. (24). Packing channel-free and in two-cell channels. (25). Packing in impassable unicellular channels. (26). I - during known construction. (27). II - with the known heat losses.

Page 242.

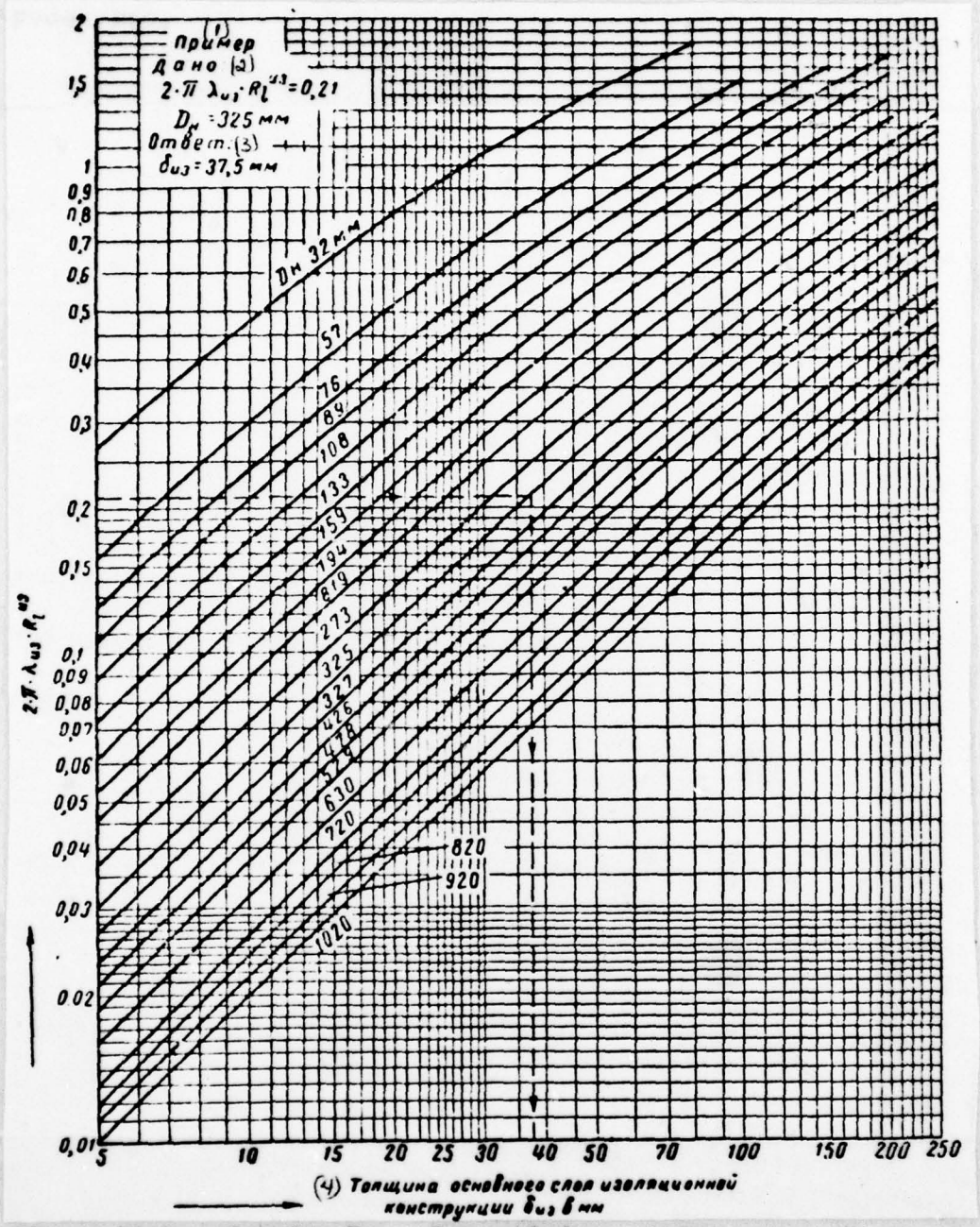


Fig. 13.1. Graph for determining thickness of base layer of insulation construction.

Key: (1). Example. (2). It is given. (3). answer/response. (4). Thickness of the base layer of insulation construction mm.

Page 263.

The complete thermal resistance of the isolated/insulated heating mains during the known constructions of heat insulation are defined as sums of thermal resistance according to the circuit, given in table 13.8, according to formulas (13.5-13.11).

Designations, accepted in table 13.8.

$d_н$ is a diameter of the isolated heating main in m;

$d_{нз}$ - the diameter of the base layer of insulation construction in m;

$d_к$ - the diameter of insulation construction in m;

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6 OF 6
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$d_{вн.изн}$ - the diameter, equivalent to the internal perimeter of the section/cut of channel and equal to $P_{вн}/\pi$, in m;

$\lambda_{из}$ - the coefficient of the thermal conductivity of the base layer of insulation construction kcal/m h deg;

$\lambda_{п}$ - the coefficient of the thermal conductivity of a cover layer in insulation construction in kcal/m h deg;

$\lambda_{гр}$ - the same, soil in kcal/m h deg;

$\alpha_{н}$ - heat-transfer coefficient of the surface of insulation construction into the environment in kcal/m^2 h deg;

$\alpha_{изн}$ is the same, from air in channel to its internal surface in kcal/m^2 deg;

h - the depth of the laying of heating main of up to its axle/axis in m;

R_{l} the complete thermal resistance of the isolated/insulated heating main in m h deg/kcal;

$R_{l_{гр}}$ - the thermal resistance of the insulation construction

of heating main in m h deg/kcal;

$R_i^{из}$ - the same, the base layer of isolation/insulation of heating main in m h deg/kcal;

$R_i^{п}$ - the same, the protective coating of isolation/insulation of heating main in m h deg/kcal;

$R_i^{н}$ - the same, to heat emission of the surface of isolation/insulation of heating main into surrounding medium in m h deg/kcal;

$R_i^{гр}$ is the same, soil with respect to the base layer of isolation/insulation of heating main in m h deg/kcal;

$R_{i_{кан}}^{гр}$ - the same, channel, equal to thermal resistance to heat emission of air within channel its wall in m h deg/kcal;

$R_i^{кан}$ - the same, soil with respect to the internal section/cut of channel in m h deg/kcal;

$R_{i_{кан}}$ - total heat resistance of channel and soil around it, equal to $R_i^{кан} + R_{i_{кан}}^{гр}$, in m h deg/kcal;

k - distance on the horizontal between the axle/axes of heating mains in m;

$R_{1,2}$ is a factor of the thermal resistance of the mutual effect of heating main with packing in two-cell impassable channels or shells without the air space, equal to

$$R_{1,2}=\frac{\ln\sqrt{1+\left(\frac{2h}{k}\right)^2}}{2\pi\lambda_{rp}} \text{ m h deg/kcal;}$$

$R_{i1,2}$ - the additional thermal resistance of the mutual effect of heating mains for the feeding heating main in m h deg/kcal;

$R_{i2,1}$ - the same, for a reverse/inverse heating main in m h deg/kcal;

ψ_i - the dimensionless coefficient, which determines for the feeding heating main the additional thermal resistance of the mutual effect of heating mains with packing in two-cell impassable channels or shells without the air space;

ψ_2 is dimensionless - the same, for a reverse/inverse heating main;

$\psi_{1кан}$ is the coefficient, which determines for the feeding heating main the additional thermal resistance of the mutual effect of heating mains with two-funnelled packing in unicellular impassable channel;

$\psi_{2кан}$ - the same, for a reverse/inverse heating main.

The values of heat-transfer coefficient from the surface of thermal insulation construction into surrounding air and heat-transfer coefficient from air within channel to the wall of channel $\alpha_{кан}$ are accepted:

in impassable channels $t_н=t_{кан}=7$ kcal/m² h deg;

in passage channels and locations - $t_н=9$ kcal/m² h deg;

in the open air

at wind velocity 5 m/s $t_н=10$ kcal/m² h deg.

		10	$t_н=25$;	
		15	$t_н=30$	

The thermal resistance of the base layer of insulation

construction are defined both the difference according to the formula

$$R_l^{из} = R_l - R_l^{т} \quad \text{м}^2 \cdot \text{h deg/kcal}; \qquad (13.33)$$

where $R_l^{т}$ is a sum of the particular thermal resistance of the isolated/insulated heating main, with the exception of the thermal resistance of the base layer of insulation construction of м² h deg/kcal.

The thickness of the base layer of insulation construction is determined from the value of the parameter

$$\ln\frac{d_{из}}{d_н} = 2\pi\lambda_{из} R_l^{из};$$

a) by analytical calculation according to the formula

$$\delta_{из} = \frac{e^{2\pi\lambda_{из} R_l^{из}} - 1}{2} d_н \text{ м}, \qquad (13.34)$$

where
e = 2.71828 - Naperian base or

b) according to the curve/graph of Fig. 13.1.

13.3. Determination of the temperature in the different points of the temperature field of insulated conduit/manifold.

The temperature of air within impassable channel $t_{в.к}$ is determined from the formulas:

a) with multitube packing in the unicellular channel

$$t_{в.к} = \frac{\frac{t_1}{R_{l\,тр1}} + \frac{t_2}{R_{l\,тр2}} + \cdots + \frac{t_n}{R_{l\,тр(n)}} + \frac{t_{гр}}{R_{l\,кан}}}{\frac{1}{R_{l\,тр1}} + \frac{1}{R_{l\,тр2}} + \cdots + \frac{1}{R_{l\,тр(n)}} + \frac{1}{R_{l\,кан}}} °C; \quad (13.35)$$

b) with single-pipe packing in unicellular channel and for each cell with two-funnelled packing in two-cell channel

$$t_{в.к} = t - (t - t_{гр}) \frac{R_{l\,тр}}{R_l} °C. \quad (13.36)$$

In these formulas:

t, t_1, t_2,... t_n is temperature of heat carrier in each conduit/manifold in °C;

$t_{гр}$ - the temperature of soil at the depth of the laying of the axle/axis of conduit/manifold in °C;

$R_{l\,тр}$, $R_{l\,тр1}$,... $R_{l\,тр(n)}$ are the thermal resistance of the insulation construction of each conduit/manifold in m h deg/kcal;

R_l - the complete thermal resistance of the

isolated/insulated conduit/manifold in m² h deg/kcal;

$R_{1\,kan}$ – the total particular thermal resistance of channel and soil around channel in m² h deg/kcal.

Temperature on surface of a cover layer of insulation construction is determined from the formula

$$t_{из} = t - (t - t_0)\frac{R_l^{из}}{R_l}\ °C, \qquad (13.37)$$

where t_0 the ambiant temperature degree °C.

With overhead laying $t_0 = t_в = t_{возд}$; with underground laying $t_0 = t_{гр}$.

Page 114

Temperature on surface of cover layer of insulation construction is determined from the formula

$$t_в = t - (t - t_0)\frac{R_l^{из} + R_l^{п}}{R_l}\ °C, \qquad (13.38)$$

where $R_l^{п}$ is particular thermal resistance of a cover layer of insulation construction in m² h deg/kcal.

The temperature in any point of soil t_{xy} (Fig. 13.2) with coordinates x and y is determined to the formulas:

a) with channel-free single-pipe packing in the cylindrical isolation/insulation

$$t_{xy} = t_0 + (t - t_0)\frac{R_l^{гр}(xy+h)}{R_l}\ °C; \qquad (13.39)$$

b) with channel-free two-funnelled packing in cylindrical isolation/insulation and in the common/general/total cast isolation/insulation of the rectangular cross section

$$t_{xy} = t_0 + (t_1 - t_0)\frac{R_l^{гр}(xy+h) + R_{l\,1.2}}{R_{l1}}\ °C; \qquad (13.40)$$

c) with packing in the unicellular inpassable channel

$$t_{xy} = t_0 + (t_{в.к.} - t_0)\frac{R_l^{гр}(xy+h)}{R_{1kan}}\ °C; \qquad (13.41)$$

d) with packing in double-cell impassable channel

$$t_{zg} = t_0 + (t_{g.k1} - t_0)\frac{R^{rp}_{l_1(xy-h)} + R_{l1.2}}{R_{l\,kan} + R_{l\,1.2}}\,^{\circ}\text{C}. \quad (13.12)$$

In these formulas:

t_{rp} is temperature of soil at the depth of the laying of the axle/axis of conduit/manifold in °C;

$t_в$ - the temperature of surrounding air in °C;

h - the depth of the laying of conduit/manifold of up to axle/axis in m;

x - distance from the point for which is determined the temperature, to the vertical plane, passing through the axle/axis of conduit/manifold with the larger temperature of heat carrier or unicellular impassable channel, in m;

y - distance from the earth's surface to point with coordinates XY in m;

R^{rp}_l; $R_{l\,1.2}$; $R_{l\,kan}$ - the particular thermal resistance, determined

by formulas given above, in m h deg/kcal;

R_l - complete thermal resistance in m h deg/kcal;

t - the temperature of heat carrier in °C;

$t_{п.к}$ - the temperature of air in impassable channel in °C;

$t_в$ - ambient temperature is accepted:

with h > 0.7 m $t_в - t_{гр}$ into °C;

with h > 0.7 m $t_в - t_{подп}$ into °C;

$R^{гр}_{l(xy+h)}$ - the thermal resistance of exterior layer of soil after point with coordinates x and y; it is determined from the formulas:

with y ≥ 0.7 m

$$R^{гр}_{l(xy+h)} = -\frac{\ln \sqrt{\frac{x^2+(y+h)^2}{x^2+(y-h)^2}}}{2\pi\lambda_{гр}} \text{ m h deg/kcal;} \quad (13.43)$$

with y < 0.7 m

$$R^{rp}_{l(xy+h)} = \frac{\ln \sqrt{\frac{x^2+\left(y+h+\frac{2\lambda_{rp}}{a_н}\right)^2}{x^2+(y-h)^2}}}{2\pi\lambda_{rp}} \quad (13.44)$$

m h deg/kcal.

Designations with the subscript are related to indices for a conduit/manifold with the larger temperature of heat carrier.

During the determination of the temperature in any point of the surface of soil t_z one should use the given above formulas, accepting $t_0 - t_{нар}$ into °C, and value $R^{rp}_{l(xy+h)}$ equal to:

$$R^{rp}_{l(xy+h)} = \frac{\ln \sqrt{\frac{x^2+\left(h+\frac{2\lambda_{rp}}{a_н}\right)^2}{x^2+h^2}}}{2\pi\lambda_{rp}} \quad (13.45)$$

m h deg/kcal.

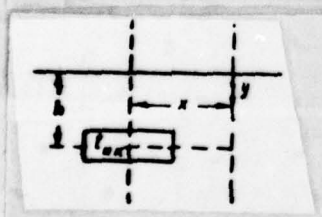


Fig. 13.2. Cross section of arrangement of heating main of underground packing.